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Journal of the AMERICAN STATISTICAL ASSOCIATION

MARCH 1946

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VOLUME 41 NUMBER 233

American Statistical Association

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JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION

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THE ADVANCING STATISTICAL FRONT*

WALTER A. SHEWHART
Bell Telephone Laboratories

THE ATOMIC BOMBS on Hiroshima and Nagasaki have made the world conscious, as perhaps no other event has done, of the potential significance of applied science. This war revealed to all that the cooperation of scientists on a gigantic scale literally revolutionized the method of carrying on wars. By the grace of God, the nations of the world have been given another chance to live in peace—another chance to explore the endless frontier of science in search of new ways of constructively serving mankind.

Most people will agree that the problems of war are inherently simpler than those of attaining the full advantages of science in a world at peace. For war is a simple business in the sense that the objectives are clear and heartily supported by an overwhelming majority of the citizens of a nation; whereas peace-time problems do not have the same dramatic intensity, immediacy, and urgency to each citizen. However, the atomic bomb has brought people to appreciate the importance of the *end* to which science is applied. All shudder at the thought of the destructiveness of another war; all like to dream of the world of tomorrow in which the object of applied science is the satisfaction of human wants. However, these wants cannot be scientifically determined without appeal to the sampling procedures of the statistician. To the citizen of a democracy there is certainly some dramatic significance in the fact that the statistician must be called in to sample human wants in order that science may be applied effectively in peace.

It seems fitting that, at this first annual meeting after the catastrophic war through which we have just passed, our attention should be directed toward the role that statistics can play in the years ahead in

* Address as retiring president of the American Statistical Association, Cleveland, Ohio, January 26, 1946.

making science *serve* humanity and toward the role that statisticians can play in giving each individual some appreciation of the dramatic intensity, immediacy, and urgency to him of some of the problems that the statistician alone can solve. With this thought in mind, I have chosen to speak on the advancing front of statistics in its service, directly and through other scientists, to the members of society as *individuals*.

If statistics can be made to minister to *all* the people, if the majority of the people can be made to realize this contribution of statistics, if those who practice statistics follow a strict code of conduct, if statisticians assume their responsibility for the proper training of neophytes before turning them loose as statisticians, then the future of the statistical profession is assured.

In the established sense of the term "profession" as applied to law, medicine, and religion, there is an implication of a devotion to a higher purpose than that of personal profit or the earning of a livelihood. Tonight I wish to keynote ministering to the people at large as an essential requirement of any profession. At some time or other between the cradle and the grave, every one of us calls upon members of the medical, legal, and religious professions. In so far as these serve us well, we come to appreciate them as members of their profession because we recognize that through long years of study and training they have placed themselves in a position to do for us what we cannot do for ourselves. If statistics can be made to serve each of us in a way that we individually recognize and appreciate, statisticians will no longer be referred to in some quarters as the showgirls of the market place because they live by their figures alone.

The high purpose of a diverse group can be built up and maintained only by an effective organization. By getting a perspective of the advancing research front and the vast armies of pure and applied scientists with whom we must cooperate if we are to make our greatest contribution to the service of science, we can come to realize fully the need for a strong professional statistical organization.

THREE TYPES OF SCIENTIFIC RESEARCH

As a background for what follows, it is essential that we distinguish between three broad and somewhat overlapping categories of research. In the recent report,[1] "Science, the Endless Frontier," by Vannevar Bush, Director of OSRD, to the President of the United States on a

[1] United States Government Printing Office, Washington, 1945.

program for post-war scientific research, the following three categories of research are recognized and briefly described: pure research, background research, and applied research and development.

Pure research is there defined as research without specific practical ends. It is directed toward the acquisition of knowledge and the understanding of nature and its laws. *Background* research is typified by the collection of economic, business, census, meteorological, and other types of data; the determination of physical and chemical constants; and the establishment of standards of quality for foods, drugs, and other manufactured materials. *Applied* research is generally directed toward some practical end determined by human wants and it is usually expected that the cost of such research will be met through the benefits that accrue from the research itself.

THE STATISTICAL FRONT IN THE THREE FIELDS OF RESEARCH

Pure Research. Since the turn of the century, great progress has been made in extending the statistical front in pure research. Advances have been made in the field of the statistical description of stellar phenomena by Chandrasekhar and others; in the development of statistical mechanics by Einstein, Bose, Fermi, Dirac and others; in the statistical description of meteorological phenomena; and in the development of statistical theories in genetics and many other fields. Statistics has progressed also in psychometrics and econometrics. But perhaps the greatest progress within the past two decades has been in the field of mathematical statistics along the lines typified by the abstract material published in the *Annals of Mathematical Statistics.*

Such work has been highly individualistic. Much of it has been done by those unknown to most of the members of the American Statistical Association. In fact, many of those who have done most to extend the frontiers of mathematical statistics are not known officially as statisticians: Even R. A. Fisher, Hotelling, and Wilks are not listed as statisticians in their college registers. Likewise the men who have contributed to the knowledge of nature through the application of statistics are seldom known to their fellow scientists as statisticians but rather as professional men in the subject matter field wherein they contributed. Statistics, in other words, has no particular subject matter field solely unto itself.

Moreover, most of the contributions of statistics to the different subject matter fields are mathematical in character; and in so far as such contributions are mathematical, it is little wonder that fellow scientists often question the existence of a statistical front as such.

Many think simply of the different subject matter fronts while others think of statistics as a part of the mathematical front.

Let us pause to examine the significance of this situation from the viewpoint of professional organizations in the field of statistics. To maintain an advancing front in *pure* statistical research both in the subject matter fields and in mathematics requires support as does pure research in every field. It is perhaps true that each subject matter field, in so far as pure research is concerned, can obtain support for the development of the statistical aspects of nature essential to that field. Those engaged in pure research in the separate fields will undoubtedly recognize the need for courting the mathematical statistician engaged in extending the boundaries of mathematical statistics per se, for perhaps never before in the history of science have scientists in the subject matter fields appreciated so wholeheartedly the contributions of mathematics. In fact, scientists are coming more and more to realize that most, if not all, theories of nature are mathematical in character at least to the extent that the idealized abstract models of natural phenomena are described in mathematical terms. There is, of course, a need for the mathematical statistician to come into contact with the problems revealed by nature in the separate sciences if mathematics is to contribute to the solution of such problems.

Those working to extend the boundaries of mathematical statistics need to have an organization such, for example, as the Institute of Mathematical Statistics to serve as a go-between for pure mathematics on the one hand and *pure science* on the other. To their fellow researchers in other fields of pure science men working in this realm of statistics will probably always be known primarily as mathematicians. Certainly to those working in the fields of background and applied science and to the public, such statistical research workers will probably always be known as mathematicians. Hence, so long as we think of the contributions of statistics to pure research, we may question the need for an organization beyond that of mathematical statisticians. When, however, we consider the service to the public of pure statistical research through its contributions to background and applied research, we find that an organization representing the common interests of all statisticians is a necessity. Otherwise we cannot fulfill our obligations to the public upon which we must depend in the end for recognition and support.

Background and Applied Research. Turning to the fields of background and applied research, three points should be kept in mind: 1) such research must involve the *cooperation* of many individual ap-

plied scientists, sometimes literally hundreds, 2) such research is directed toward obtaining knowledge useful to many individuals and sometimes to practically the whole public, and 3) the usefulness of such work must be recognized by those who receive the benefits in order to gain their financial and other support: applied research must pay its own way.

What I want to do is to indicate in some detail the endless field open to the statistician in applied research and to indicate briefly some of the problems involved in obtaining the cooperation of individual applied scientists and of groups of applied scientists in carrying out a few major lines of application that are of significance to the public.

First, let us consider simply the background research of standardization as carried on by groups like the American Standards Association and the American Society for Testing Materials. Work on standardization projects often requires the cooperation of many different kinds of scientists representing the public, industry, and government: the number of such projects runs into thousands. Each such standard is, in general, arrived at through committee action often extending over several years: many compromises must be made, some because of a lack of scientific knowledge, some because of economic requirements, and some because of other limitations. Each standard must be, as it were, a tailor-made job that is satisfactory to different group interests. Most of the applied scientists cooperating in such a project are not familiar with statistical theory and application; many of them are, in fact, antagonistic to the statistician. Yet these scientists are in the saddle and decide what shall be done.

Even if we assume that we have the ideal condition in which a standardizing committee is completely sold on the applications of statistics, there remains the problem of translating the contributions of the statistician into the written specification in a way that will be understood by those who use it—a group that often includes hundreds of people; indeed in the case of a consumer standard, thousands of people. The problem of putting statistics to work in standardization, one of the fields of background research touching all of us as consumers of foods, drugs, and other manufactured goods, is a tremendous job calling for the cooperation of applied scientists working not only as individuals but as groups. *This is not a problem that can be solved by statisticians working independently:* yet in its solution there is room for hundreds of scientists with basic training in statistics.

In applied research, let us consider only industrial research. In 1942 there were 2254 industrial research laboratories: today there are many

more. Yet I doubt that many of the directors of these laboratories have any appreciation of the potential contributions of statistics. In 1939 there were 184,230 manufacturing firms in the United States: today there are perhaps as many or more. Yet I doubt that management in any but a few of these firms is aware of the potential contributions of statistics. Of course, many employ statistical clerks and a few may even employ one or more persons called statisticians but their statistics is usually limited to business and economics. There is a big gap to be filled between the contributions of the mathematical statistician in the Annals, for example, and the appreciation of the value thereof on the part of management in any large percentage of industrial laboratories and manufacturing firms. Nevertheless, statisticians have a great opportunity in this almost unlimited field to serve the public at large as users of the manufactured goods turned out.

The contribution of statistics in these two fields of applied research lies not so much in solving the problems usually put to the statistician by those not statistically trained as in helping to coordinate the steps of specification, production, and inspection. This may be considered as a scientific experiment for making the most efficient use of human effort in the production of goods to satisfy human wants. The long range contribution of statistics depends not only upon getting many highly trained statisticians into industry but also upon creating a *statistically minded new generation of those physicists, chemists, engineers, and others* who will develop and direct the mass production processes of tomorrow.

Let us look at the problem of interesting the members of professional organizations in the three fields of pure, background, and applied research. Broadly speaking, professional scientific organizations may be classified under these three headings although the boundaries are not distinct. At the pure research level, we have those organizations representing the basic natural and social sciences; at the level of applied research, we have large professional groups such as the engineering societies, several of which have memberships of 20,000 or more; at the level of background research we have the American Society for Testing Materials, The American Standards Association, and certain trade associations. By and large, these professional groups with a combined membership of more than a hundred thousand are responsible for the development of the scientific research front. These groups in the end will determine to what extent, if any, statistical methods will be used in their work. We must first get the membership of these scientific groups to give us a chance to show how statistics can help. Then we must work in close cooperation with these groups in putting statistics to work for

the public good. Statisticians must assume a large part of the responsibility for finding out how they can best serve the thousands of scientists in the different subject matter fields and then they must cooperate with other professional groups in the different subject matter fields to see that statistical method is applied wherever it will yield useful results.

THREE WAYS OF SERVING FELLOW SCIENTISTS

Three ways of serving fellow scientists are through joint meetings, through joint committees, and through publications. For years our Association has been accustomed to holding joint meetings with other groups, particularly in the social sciences. More recently joint meetings have been held with the Institute of Mathematical Statistics and the Biometrics Section has held many joint programs with groups having interests similar to theirs. By and large, however, there have been no joint meetings with the majority of the scientific groups primarily responsible for pure research in other than social science fields nor with the many large groups responsible for background and applied research.

A joint committee type of approach to applied research in engineering was started in 1929. In that year E. B. Wilson, then President of the American Statistical Association, cooperated with a small group of statisticians in getting the interest of certain professional engineering groups in setting up what was and is called the Joint Committee for the Development of Statistical Applications in Engineering and Manufacturing. This committee was actively sponsored by the American Statistical Association, the American Society for Testing Materials, The American Society of Mechanical Engineers, and the American Mathematical Society. The membership was made up of two representatives from each of these societies. This committee, working in cooperation with the officers of the sponsor societies, has been largely influential in initiating most of the activities that have taken place since then in organizing statistical effort in the engineering field.

It was also realized at that time by the same group of statisticians that it was desirable to launch a committee interested in the application of statistics to the background research of standardization. Such a committee was set up and has been active ever since in the American Society for Testing Materials. A short time before the war another small group of statisticians recognized the desirability of getting formal action on the application of statistics in quality control through the standardization of simplified methods. With the cooperation of the War Department and the American Standards Association a committee

was set up under the auspices of the Amerian Standards Association. This committee turned out three emergency war standards in statistical quality control and these were used extensively not only in America but also in Australia, Canada, and England.

During the early years of the war, there were often discussions by the Board of the American Statistical Association about the need for a joint committee representing some of the major fields of war research, more nearly on the pure research level, to act in an advisory capacity on the applications of statistics. Nothing was done officially by the Association, but statisticians working independently in cooperation with the officers of the National Research Council and particularly with Dean Eisenhart, chairman of the Division of Physical Sciences, organized in 1943 a committee on applied mathematical statistics with subdivisions on physics, chemistry, psychology, economics, mathematical statistics, biology, and engineering. This committee has had from the beginning liaison members with the War and Navy Departments and the War Production Board. More recently, liaison representation has been secured on the part of the National Physical Laboratory of Great Britain and the Council for Scientific and Industrial Research of Australia. The latest development in this organized committee effort is the establishment of a committee, under the joint direction of the National Research Council and the Social Science Research Council, charged with the study of the scientific problems of measuring public opinion, attitudes, and consumer wants.

Much of the work of these committees has been of an advisory nature. For example, the joint committee on engineering, which is now sponsored not only by the original sponsors but also by the Institute of Mathematical Statistics and the American Institute of Electrical Engineers, has cooperated with different engineering groups in setting up special committees on the application of statistics within these groups and in arranging for the presentation of papers on applied statistics on the programs of many of the engineering societies. Just recently such a committee was set up in the American Institute of Electrical Engineers.

Some of these committees have operated to secure not only national cooperation but also international. For example, the Joint Committee, through its sponsors, was influential in starting the movement in Great Britain that led to the organization of a committee under the auspices of the British Standards Institution. Interest thus aroused has been credited by our English friends as the spark that started the movement which led to the formation of the Agricultural and Industrial Research Section of the Royal Statistical Society.

To date, however, such effort has been largely individualistic even perhaps to the extent that few statisticians in either the American Statistical Association or the Institute of Mathematical Statistics are aware of it. Furthermore, these committees have only scratched the surface of the work that needs to be done by way of cooperation with other scientific groups. Perhaps they set a pattern, however, that deserves more study on the part of those interested in the statistical profession. In passing, it may be remarked that in setting up such joint committees it seems desirable that at least two representatives be chosen from each participating group. One should be an "elder statesman" in the subject matter field of the group, in addition to being a person who is broad-minded and interested in all new developments that might contribute to the work of his profession. At the same time he should be a sympathetic but hard-boiled critic. The other representative should not only be qualified in the particular subject matter field but also in the technical applications of statistics in that field.

Let us turn now to the problem of serving our fellow scientists by means of publications. At least two media must be considered: journals of the many different scientific organizations, and a thoroughly up-to-date statistical journal containing methodological and subject matter articles of general interest to statisticians working in the three fields of research. To date, statisticians working as individuals have published articles in many professional journals, and the editorial board of the *Journal of the American Statistical Association* plans to provide a journal of high calibre that will carry material of broad general interest. For example, the article by Wald in the September issue of the *JASA* is of potential interest to members of many professional organizations in the field of pure and applied science. Hence progress is being made. However, we still have a long way to go in developing a well-thought-out plan for reaching the thousands of scientists in different subject matter fields.

THREE WAYS OF SERVING THE PUBLIC

Let us now consider some of the ways in which statisticians serve the public. As already noted, it is essential for the existence of a strong professional organization that the public recognize to some extent the service rendered by its members. If, for example, the public becomes aware that by extending the use of statistics in many fields of research the potential contributions of that research in satisfying human wants may be maximized, it will not only appreciate the statistician but it may also bring pressure to bear wherever necessary to see that desirable applications of statistics are made.

Since, as already noted, the professional scientific groups in the separate subject matter fields mainly determine the extent to which statistics will be used, I shall use the three-fold classification of contributions of research that are essential to the public proposed in Dr. Bush's report. These are in the war against disease, in the maintenance of national security, and in increasing public welfare. By adopting this classification we may more easily see how the need for the contribution of the statistician fits into the picture of the need for scientific progress presented in this report and now being discussed so extensively in scientific literature.

War Against Disease. The study of vital statistics, including the study of epidemics and the causes of disease, was one of the earliest fields to which statisticians contributed. Statistical studies to determine hereditary susceptibility to disease have long been of interest from the viewpoint of preventive medicine. The determination of the effects of drugs and medical treatments is inherently a very complicated sampling process. Statistical methods, of course, have been long used in studying the effects of specific drugs in the laboratory. Here statistics plays an important part not only in the interpretation of results but also in the design of efficient experiments. Statistics also plays an important role in the study of the effects of different kinds of bacteria, climatic conditions, and the like, on health. It should not be hard to get across, even at the high school level, some appreciation of such uses of statistics. In the whole field of foods and dietetics the public could be made to appreciate something of the importance of statistics.

National Security. For years government agencies have employed most of the statisticians. Their services have long been recognized as of great importance in the collection and assembly of factual information about the supply and demand of labor as well as the supply and demand of manufactured goods and agricultural products. The statistician has for years played an important part in agricultural experimentation, in the study of social trends and in the general field of economics. In so doing, he has made available information of great value to those responsible for planning national security.

However, at the beginning of the present war there was little appreciation of the value of the statistician in government other than in the fields mentioned above. Even in setting up the National Roster, the profession of statistics was given little recognition. However, during the war this situation was greatly modified. Within such agencies as the War and Navy Departments, the War Production Board, the Office of the Surgeon General, and the National Defense Research Committee,

statisticians were given a chance to make important contributions. These extended beyond the business and social fields into the fields of background and applied research in the natural sciences. If and when the record can be made public, we will find a surprisingly large contribution to the war effort in the fields of personnel placement, operational research, development of improved war materials, and the control of the quality of much of the material used by the Armed Forces.

However, the organization of such statistical effort depended primarily upon the initiative of small groups of statisticians. Had we had at the beginning of the war, a strong professional organization interested in all fields of applied research, I think that our contribution would have been even greater. Prior to the war statisticians had not given sufficient attention to the developing front of statistics along new lines, particularly in the field of applied natural science. Organized planning was so inadequate that there were not enough statisticians qualified even to teach the large numbers of technicians required.

From the viewpoint of future security, a strong professional organization is needed to keep building sufficient public support for the many *new* fields of application that are likely to be of use in developing our national security. Moreover, if the potential contributions of statistics in this field are to be realized, much remains to be done in getting across to a large percentage of the public the part played by statistics in this war. Professional organizations in other fields of applied science have already taken steps to get recognition for their work. In the American Statistical Association, the officers and many of the members have given much consideration to this problem. One of the steps being considered is the publication of technical articles in the *JASA* to acquaint all statisticians with war-time contributions. This, however, is not enough. We need to reach great numbers of people who never see the *JASA*. Through short articles and editorials in the press and popular magazines, an effort should be made to indicate in an understandable manner not only the contributions that statistics made in the war but also the necessity of continually developing such applications as a part of any plan for security.

Public Welfare. In a democracy, public opinion and attitudes play an important role. In so far as public policies are determined upon the basis of public opinion, it is certainly of interest to everyone that such opinion be measured *in the best possible way*. All of you are well aware of the complicated statistical sampling problems as well as the psychological, economic, and other problems involved in the measurement of public opinion. However, it would not be extremely difficult, I believe,

to make most people have an appreciation for some of the more elementary statistical problems involved.

Even a group of men sitting around an old pot-belly stove in a backwoods general store could be made to see the fallacy in the *Literary Digest* Poll. If the public can be convinced of the importance of using adequate statistical care in such work, is it not reasonable that they would support a professional organization that would assume the responsibility for providing adequate statistical techniques for those working in this field and for acquainting the public with information that will help individuals to form valid judgments on questions involving public opinion. It seems to me that this is one of the public services that the Association can render.

Another example of the usefulness of statistics to all individuals is the establishment of consumer standards of quality. One aspect of this problem of particular interest is that it requires the cooperation not only of applied natural but also of applied social scientists. Much work, of course, has been done by members of the Marketing Research Association, by certain government agencies, and by standardizing groups. Success in this field is, of course, closely tied up with success in solving the problems involved in measuring public opinion and attitudes. So far, a large part of the work in consumer standards has been in determining preferences between things known to the consumer. In many cases, more needs to be done by way of determining what *might* sell, and what might give even greater satisfaction to customers. Here I am thinking primarily of what might be done at the applied research level by a team composed of physicists, chemists, psychologists, economists, market research men, statisticians, and possibly physiologists in solving some of the problems of establishing consumer standards. During the past two years, these problems have been discussed in several issues of the *Bulletin* of the American Society for Testing Materials and the American Standards Association publication.

To make further progress it is essential that statisticians, familiar with what is known at the present time about the science of measuring opinion and attitudes, cooperate with professional groups like the American Standards Association and the American Society for Testing Materials to establish standards in terms of physical, chemical, and other properties. More than this, it would be highly desirable if we could find some objective physiological measure of human reactions that would be more reliable in many instances than verbal expression.

The problem of standardization is difficult even when considered in

terms of theoretically measurable characteristics of a product: when we couple with this the problem of determining in a quantitative manner the correlation between human reaction and physically measurable characteristics of manufactured goods, it is obvious that the problems are vastly more complicated. All of these problems are inherently statistical and unless statisticians as a professional group assume their responsibility in helping to solve them, statistics will have lost one of its great opportunities to serve the public in a way that the public can understand. If, on the other hand, these problems are attacked in a half-hearted manner and are muffed, the day of full public recognition and appreciation of the statistician will be greatly delayed. In other words, we have here a frontier for applied statistical research of the highest order. We have here a problem in which the public is greatly interested not only as individuals but as organized groups—we have here a problem that the public *wants* solved.

In closing this section on public welfare, let us consider briefly the question: What can statisticians contribute to general education? The recent report on *General Education in a Free Society*, published by Harvard University, gives the following definition of general education: "It (general education) is used to indicate that part of a citizen's whole education which looks first of all to his life as a responsible human being and citizen; while the term 'special education' indicates that part which looks to the citizen's competence in some vocation."

I have recently read not only the Harvard report but many other discussions on general education and I am pleased to find that several emphasize the importance of some knowledge of scientific method as a part of general education. In a few cases, the authors mention statistics but not in a way that indicates any relationship to scientific method. This is not surprising because there has been little effort in statistical teaching to emphasize how statistical method is related to the three steps in scientific method, namely, hypothesis, experiment, and test of hypothesis. If the student were made to appreciate that, because of the statistical nature of observable phenomena, it is often necessary to replace the three steps by statistical hypotheses, statistically designed experiments, and statistical tests of hypotheses, he would appreciate the developing growth of scientific method and the contribution of statistics thereto.

From the viewpoint of general education, statistics is *not* simply a tool as is so often stated but *a scientific way of looking at the universe:* statistical method is not something apart from scientific method but *is* scientific method adjusted to the generally accepted view that science

is not exact but only probable. Statistics is like the well-dressed bride in that statistics "wears":

Something old: scientific method.

Something new: *improvements on each of the three steps in scientific method.*

Something borrowed: Mathematics and logic.

Something blue: Contributions in the "blue chip" class in every subject matter field.

CONCLUDING REMARKS

The statistical front is the whole field of science. Outposts of that front exist in every subject matter field of research. Many outposts are manned by small scouting parties of pioneering souls: others are well-organized groups like the Biometrics Section of the American Statistical Association, the Econometric and Psychometric Societies, the Institute of Mathematical Statistics, and the American Marketing Association. Some of these outposts have already advanced out of sight of the others; in no instance are the lines of communication adequate—even worse, there is no available map showing the location, personnel, and objectives of these outposts.

Picture these outposts on the scientific frontier each with a mission to perform that is of vital interest to the public, but without any *one* headquarters statistical organization to which appeals can be directed for the latest statistical results from the similar outposts in other fields of pure, background, and applied research; without any one headquarters organization to stimulate the training of new recruits in the separate subject matter fields; without any one headquarters organization to maintain adequate public support for their work vital to our national security, war against disease, and public welfare.

To insure continued advancement on the statistical front, we need a strong professional organization backed by *all* statisticians working in the many different subject matter fields: an organization whose purpose shall be to foster in the broadest manner the *science* of statistics and its applications; and to promote a unified, effective, organized effort in advancing the common interests of all professional statisticians.

To this end, such a professional organization needs to conduct joint meetings and conferences with many organizations in the fields of pure, background, and applied research with whom official contact has never been made in the past; to establish joint committees with other scientific groups wherever necessary; to produce and distribute publications

devoted to statistical methodology and statistical knowledge of common interest to all professional statisticians; to provide the public through the press, lecture platform, and radio with reliable information about the science of statistics and its contributions; and to stimulate statistical research and promote high professional standards in all statistical work.

I hope and believe that the American Statistical Association with the cooperation of other organized societies interested in statistics, can be developed into a strong organization to serve the common interests of *all* professional statisticians in these groups.

ON THE DESIGN OF A SAMPLE FOR DEALERS' INVENTORIES

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I. STATEMENT OF THE PROBLEM

Administration of the tire-rationing program required current and reliable knowledge of the numbers of passenger, truck, and other civilian-grade tires held by dealers, mass distributors, and manufacturers. To fill this need, inventories of tire dealers were taken each quarter, which together with monthly reports from tire manufacturers and mass distributors gave fairly complete information concerning stocks of tires available for civilian consumption. In the interest of speed, accuracy, guaranteed reliability, and economy, the quarterly inventories were eventually taken by sampling. These advantages of sampling have given rise to increased usage and to the development of new theory,[1] but it should be stated that the sampling plan described here depends only on comparatively simple theory.

Purpose of this paper. The immediate aim of this paper is to describe the sample of dealers used in estimating the March 1945 tire-inventory; more specifically,

i. To state the reliability desired;
ii. To describe how this reliability was achieved through the application of basic principles and simple procedures;
iii. To describe how available knowledge concerning dealers' stocks was used to minimize the number of dealers in the sample and the work-load of weighting the results;
iv. To describe the estimation of the precision actually attained, and to compare the estimate of the actual precision with the aimed-at precision. This was done by examining a subsample of the returns;
v. To estimate the gains in efficiency accomplished by stratification.

The methods herein described may be profitably used in administrative problems of business and government relating to inventories, sales, employment, or traffic, wherever conditions are similar—i.e.,

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[1] Morris H. Hansen and William N. Hurwitz, "Relative efficiencies of various sampling units," *Journal of the American Statistical Association*, vol. 37, 1942: pp. 89–94. "On the theory of sampling from finite populations," *Annals of Mathematical Statistics*, vol. xiv, 1943: pp. 333–62.

where a complete list of possible respondents is available along with other information such as size or type, which may serve as useful criteria for stratification.[2]

Definition of the universe. The universe to be covered was by definition the list of dealers on record with the OPA. This list contained the original registrations at the beginning of rationing (October 1942), plus dealers authorized subsequently ("new authorizations"), minus deletions that were made when notice was received that a business was defunct. Changes in name and address, and unreported defunct businesses, created the usual problems in interpreting nonresponses.

Evils of nonresponse; advantages of sampling. Nonresponses would be harmless if it were certain that a nonresponding dealer is out of business or has no tires. But unfortunately a nonresponse may mean other things as well—moved, change in name, or business as usual at the same address, coupled with inadvertance or inability to fill out the questionnaire. Every effort should therefore be made to keep the list trimmed of dead wood and to evaluate nonresponses by personal calls on a subsample.[3]

The minimum in nonresponses can be reached much easier with a sample than with a complete coverage because there are fewer of them, and the district offices are not bogged down with more calls on dealers than is humanly possible to make; and moreover, the sample almost always, by the principle of optimum allocation (vide infra), contains a preponderance of big dealers employing bookkeepers able to supply the figures and even taking pride in doing so. In illustration, the "complete count" of September 1944 resulted in 24,015 nonresponses or 17 per cent of the 140,989 questionnaires mailed out, whereas in the December 1944 and March 1945 samples the nonresponses were only 1.2 per cent and 3.9 per cent respectively of the 16,000 questionnaires mailed out, and be it noted that both these samples included a sample

[2] Information on size and type is not necessary for sampling, but ordinarily such information will make possible a considerable reduction in the size of sample required to attain the reliability desired. Stratification by area alone can be expected to show some small gains in sampling efficiency. Separation of dealers into groups widely different in type and size as of the last inventory will bring further gains, provided the inventories of dealers on the date of the sample still differ widely in type and size, in which case the additional efficiency gained by applying the principle of optimum allocation (vide infra) of the sample to the various strata is often striking. Fortunately, any large list must be arranged in some systematic fashion, such as by city, type, size, and order of receipt, whatever it is to be used for; and little or no additional labor may be required to group the dealers ideally for sampling.

[3] A systematic procedure for discovering the size of subsample of nonresponses to be followed up by a field interview has been worked out by William N. Hurwitz of the Census. This procedure elicits the greatest possible amount of information for a given allotted cost (mailed questionnaire plus field follow-up). It is being introduced into government surveys at considerable saving and gain in reliability. It was first expounded by Mr. Hurwitz at one of the Seminars in Statistical Inference at the Graduate School in Washington in 1943, and later published as Appendix C in the "Working plan for the annual census of lumber produced in 1943," which is obtainable from either the Census or the Forest Service.

of the nonresponses of September. Incidentally, the average number of tires per dealer was 50 per cent higher in both December and March for this group than the average inventory of all other dealers, thus pretty well deflating the possible interpretation in which refuge is so often taken, that nonresponses can be ignored on the pretext that they are average, or are composed mostly of small dealers, or represent no stock at all. These results bear out an interesting observation that had been made in tabulating the returns from the September complete count, viz., that the last 3000 dealers that reported subsequent to the second follow-up letter sent to delinquents, actually had on hand an average of over 10 tires per dealer against an over-all average of 6 tires per dealer for the 113,000 dealers that had already responded.

Some history of the quarterly inventories. The first inventory of tires was accomplished simultaneously with registration, following which quarterly inventories were taken, at first by the "cutoff" method by which small dealers were not asked to respond. Because the list of dealers showed not only names and addresses, but the number of tires by size and type on hand and consigned as of the latest complete inventory, it was possible to cut off any class of dealer, or to classify the dealers for efficient sample design. In June 1943 a complete count was attempted, following two inventories by cutoff that had been taken in December 1942 and March 1943, subsequent to the first registration (October 1942). The quarterly cutoff was repeated in September and December of 1943, but samples were taken in March and June 1944, followed by the attempted complete count of September 1944. At this time, the number of nonresponses was huge (24,015), and proper follow-up was impossible because of the sheer enormity of the task. Worrisome discrepancies appeared between the complete count of September 1944 and the earlier samples taken in March and June, the explanation of which turned out to be the more energetic and successful follow-up of the nonresponses in the samples. This explanation was not at first accepted, and indeed was not demonstrated until the sample of December 1944 was taken. Meanwhile, a study of these discrepancies had led to a re-examination of the entire reporting system, as a result of which sampling was recommended again for the December 1944 and March 1945 inventories.

II. PRELIMINARY CONSIDERATIONS AND THE STRATIFICATION OF DEALERS

Scope of this description. This article will be limited to a description of the sampling plan as revised for March 1945. The sample for the

previous quarter (December 1944) was planned along the same lines and will therefore be mentioned only as its results were used in the plans for March.

It is important to bear in mind that data were needed concerning several types and sizes of tires (of which there are new passenger tires, new truck and bus tires, motorcycle tires, used passenger tires and tractor-implement tires). Now a dealer in the sample was expected to report his stock of all types of tires, but owing to the differing dispersions of the various types of tires amongst dealers, some handling (e.g.) motorcycle tires, and some not, some handling truck and bus tires and some not, and some handling all types, a sample of dealers that will provide adequate precision for one type of tire might not do so for another. Analysis of the dispersions of tire-stocks demonstrated that a sample producing adequate results for new passenger tires would probably suffice for other types of tires with a few minor adjustments (Part IV).

The particular kind of sampling to be described here has these characteristics:

i. Stratified sampling;
ii. Optimum allocation of sample, to provide the aimed-at precision with the minimum number of questionnaires;
iii. Simple systematic selection of dealers within strata;
iv. A definite precision-requirement, consistent with the uses that were to be made of the data;
v. A predetermined procedure for weighting the results to get unbiased estimates;
vi. A determination of the precision that was actually attained, based on a sample of the returns (Part V).

The stratification. Study of past quarterly inventories revealed two main groups of tire dealers: Group A, containing dealers reporting stocks of new truck and bus tires in September 1944; and Group B, containing dealers reporting no new truck and bus tires but reporting stocks of new passenger tires in September 1944. This division was very effective in reducing the variance in the estimated total of new truck and bus tires. Similarly, it was effective for new passenger tires, because the larger dealers were automatically thrown into one group (Group A). This is so because dealers that handle new truck and bus tires usually aim to keep good stocks of all types of tires; actually, these dealers held about 85 per cent of the new passenger tires, as well as practically all of the new truck and bus tires. On the other hand, the dealers in Group B consisted mainly of small stores and service stations

handling relatively few popular size passenger tires usually incidental to the main business.

Besides Groups A and B there were five special groups, described in Part IV. Samples were drawn from these special groups, but they were relatively unimportant; the main consideration was Groups A and B, which contained practically all of the tires.

Dealers in each of these two groups were classified according to the numbers of tires that they held in September 1944 in intervals of 10 tires, i.e., 1–9 tires, 10–19 tires, 20–29 tires, and so forth. For Group A this classification was based on new truck and bus tires, and for Group B, on new passenger tires.

Method of expansion. From Class i, consisting of N_i dealers, a sample of n_i dealers was selected (cf. Remark 3). N_i was known; n_i was determined from considerations of optimum allocation as discussed further on. If S denotes the total number of (e.g.) new passenger tires on hand in March, then

$$S = N_1\mu_1 + N_2\mu_2 + \text{similar terms for the other subclasses through all groups} \tag{1}$$

where μ_i is the average number of new passenger tires held per dealer in Class i, which consists of N_i dealers. The sample gives, not μ_i, but $\bar{x}_i$ as an unbiased estimate thereof as is indicated in Remark 1. The comparison is disclosed by their definitions,

$$\mu_i = \frac{1}{N_i}(x_{i1} + x_{i2} + \text{similar terms through all } N_i \text{ dealers of Class } i) \tag{2}$$

$$\bar{x}_i = \frac{1}{n_i}(x_{i1} + x_{i2} + \text{similar terms through all the } n_i \text{ sample dealers of Class } i) \tag{3}$$

x_{ij} being the number of new passenger tires held by the j-th dealer in the i-th class. Because $\bar{x}_i$ is an unbiased estimate of μ_i it follows that

$$\hat{S} = N_1\bar{x}_1 + N_2\bar{x}_2 + \text{similar terms for the dealers of the sample} \tag{4}$$

is an unbiased estimate of S. The adjective "unbiased" signifies that if all possible samples of dealers were drawn by the method described, and if the responses were independent of the method of drawing the sample (which is not true in practice, except when samples are drawn from files of cards already containing the responses, or in an ideal experiment wherein the response is a number written on a chip), then the average value of all the estimates so obtained would be identical

with the results of a complete count. A mathematical definition of this concept is given below. The practical problem in designing a sample is to attain the desired band of sampling error for $\hat{S}$ at the lowest possible cost to business and government.

Remark 1. An unbiased estimate is one whose "expected" value is the quantity being estimated. Mathematically, an "expected" value is defined as the sum of the products of all values which could possibly occur in a given sampling plan multiplied by their respective probabilities of occurrence. Thus for the estimate $\hat{S}$ in Eq. 4,

$$\begin{aligned} E\hat{S} &= E(N_1\bar{x}_1 + N_2\bar{x}_2 + \text{similar terms through all classes}) \\ &= N_1E\bar{x}_1 + N_2E\bar{x}_2 + \text{similar terms.} \end{aligned} \tag{5}$$

Now from Eq. 3 it follows that

$$E\bar{x}_i = E\frac{1}{n_i}(x_{i1} + x_{i2} + \text{similar terms through all } n_i \text{ sample dealers in Class } i). \tag{6}$$

The probability of including any particular dealer in the sample is n_i/N_i, wherefore the sum of all possible sample values of inventories multiplied by their probabilities of occurrence is

$$\begin{aligned} E\bar{x}_i &= \frac{1}{n_i}\left(\frac{n_i}{N_i}\cdot x_{i1} + \frac{n_i}{N_i}\cdot x_{i2} + \frac{\text{similar terms through all}}{N_i \text{ dealers in class } i}\right) \\ &= \frac{1}{N_i}(x_{i1} + x_{i2} + \text{similar terms through all } N_i \text{ dealers in Class } i) \\ &= \mu_i. \end{aligned} \tag{7}$$

Substitution of μ_i for $E\bar{x}_i$ in Eq. 5 gives Eq. 1. Thus the "expected" value of the estimate $\hat{S}$ is equal to S, which is the sum of the inventories of passenger tires of all dealers.

III. THE SAMPLE IN GROUPS A AND B

The principle of optimum allocation. There are two fundamental principles for guidance:

$$\frac{n_i}{N_i} = \frac{\sigma_i}{k} \tag{8}$$

$$\sigma_{\bar{x}_i}^2 = \frac{N_i - n_i}{N_i - 1}\,\frac{\sigma_i^2}{n_i}. \tag{9}$$

The first is the principle of optimum allocation,[4] which says that to obtain the greatest efficiency in sampling for (e.g.) passenger tires, the

[4] Optimum allocation was expounded by Neyman for simple stratified sampling in his article entitled, "On the two different aspects of the representative method," Journal of the Royal Statistical Society, vol. xcvii, 1934: pp. 558–625; pp. 579–80 in particular. Actually, Eq. 8 as given above is not strictly optimum allocation; the factor $\sqrt{N_i/(N_i-1)}$ on the right-hand side as given by Neyman has been omitted for convenience.

proportion (n_i/N_i) of dealers to be drawn into the sample from the i-th class should be proportional to the standard deviation σ_i of the passenger tires held by the dealers of this class on the date of the sample. The word "class" is used here in the general sense. It might mean a size-class within a group, or it might mean a whole group. The symbol k in Eq. 8 is a factor of proportionality and will be determined later by conditions fixed by the precision that is aimed at (see Eqs. 19 and 21).

Remark 2. Sometimes the total sample size $(n = \Sigma n_i)$ is fixed in advance by considerations of cost (and not, as here, by an aimed-at precision). For such problems it is convenient to know that the symbol k in Eq. 8 has the value

$$k = \frac{\sum N_i\sigma_i}{n} \tag{10}$$

in which case Eq. 8 gives

$$\frac{n_i}{n} = \frac{N_i\sigma_i}{\sum N_i\sigma_i}. \tag{11}$$

This equation fixes the sample n_i within a class in terms of the total sample n, supposed known. In the problem of this article, the approach was from the other direction—a desired precision was aimed at, and k determined accordingly (cf. Eqs. 19 and 21). The sample sizes n_i were then computed from Eq. 22. They of course satisfy Eq. 11, but n was not known until the n_i were computed and added up.

In symbols, the standard deviation σ_i in Eqs. 8 and 9 is defined by the equation

$$\sigma_i^2 = \frac{1}{N_i}\sum_{j=1}^{N_i}(x_{ij} - \mu_i)^2. \tag{12}$$

Eqs. 8 and 9 are intended to refer to conditions existing at the date of inventory. Actually, σ_i is known only for some earlier date (in this case, the preceding September and December), so it is necessary to approximate σ_i for the date of the sample (cf. Eq. 14). Eq. 9 gives the variance of the mean number of tires per dealer as would be obtained in an ideal experiment in which repeated samples of n_i dealers are drawn at random and without replacement from the N_i dealers. Each class of dealer will contribute a term (see Eq. 13 ahead).

Remark 3. The n_i dealers from any class were selected systematically by starting at a random point in the first interval in the file and taking out one card at a time at a constant interval throughout the file for that class. A systematic selection is much easier to carry out than any serious attempt at random selection. Moreover, systematic selection in this type of problem may introduce slight gains over a random selection, for the reason that systematic selection assures nearly proportionate representation of dealers

from each city and state, because of the arrangement of the files. This may have been of some importance because the inventories in one broad locality usually differ from those in another both qualitatively and quantitatively. On the other hand it must also be recognized that systematic selection will sometimes introduce losses. The theoretical calculations made by the Madows have not been applied to see exactly what the gains and losses of systematic sampling might be in this type of problem. The equations for random sampling are used instead under the assumption that they indicate the approximate level of the variance of this design. It should be noted that even if the variance of the systematic design were as much as 25 per cent higher than the variance of a random sample of equal size, the usefulness of the inventory obtained by the methods of this paper would hardly be affected. The authors have had the benefit of guidance from Dr. Madow in these questions.

An assumption for arriving at useable values of σ_i. The symbol $\hat{S}$ in Eq. 4 denotes the total number of new passenger tires as estimated from a sample. By the law of propagation of variances[5] the variance of $\hat{S}$ will be

$$\begin{aligned}\sigma_S^2 &= N_1^2\sigma_{\bar{x}_1}^2 + N_2^2\sigma_{\bar{x}_2}^2 + \text{similar terms for all other classes through all groups} \\ &= N_1^2\,\frac{N_1 - n_1}{N_1 - 1}\,\frac{\sigma_1^2}{n_1} + N_2^2\,\frac{N_2 - n_2}{N_2 - 1}\,\frac{\sigma_2^2}{n_2} + \text{similar terms} \\ &\doteq N_1^2\left(1 - \frac{n_1}{N_1}\right)\frac{\sigma_1^2}{n_1} + N_2^2\left(1 - \frac{n_2}{N_2}\right)\frac{\sigma_2^2}{n_2} \\ &\quad + \text{similar terms.} \qquad (13)\end{aligned}$$

The second line follows from the first by the introduction of Eq. 9, and the third line is simply a close approximation obtained by dropping the -1 in each denominator. Later on, Eq. 13 will be used as it stands for the evaluation of the precision actually attained; this will be done by evaluating each σ_1 from a subsample of the returns (Part V). Meanwhile, though, in the planning of the sample, suitable values of σ_i, σ_2, etc. must be settled upon from considerations of possible trends and dispersions of tire inventories. For the March sample there was the experience of the December sample to fall back on, which helped considerably.

It seems reasonable to suppose that the changes in dispersion taking place in the inventories of a group of dealers over a 3 or 6 months' period will be roughly proportional to their average inventory of the

[5] Propagation of variance is treated in many books on least squares and curve fitting; for example, Ch. III in Deming's *Statistical Adjustment of Data* (Wiley, 1943).

base date (Sept. '44). This is only saying that the stock of a large dealer will usually change more in either direction than the stock of a small dealer, and about in proportion to size as measured by initial inventory. Indeed, Messrs. Hansen and Hurwitz, in empirical tests in many lines of work, have found this to be a very useful assumption. It of course breaks down in the small size-classes (cf. the treatment of the smallest subclass in Table IV; and the treatment of "0-blocks" in the Part VI). With this in mind, it was perceived that in the returns from the December sample, σ_i/μ_i was roughly constant in the different size-classes of Group A and hardly exceeded 1.25. Similarly, it hardly exceeded .75 in Group B. To allow for still further dispersion during the additional 3 months between December and March it was assumed that

$$\left.\begin{aligned} \frac{\sigma_i}{\mu_i} &= 2 \text{ in Group A} \\ \frac{\sigma_i}{\mu_i} &= 1 \text{ in Group B} \end{aligned}\right\}. \tag{14}$$

These approximations are admittedly rough, as is only too obvious from Tables I and II.

TABLE I

COEFFICIENTS OF VARIATION FOR SEPTEMBER AND DECEMBER FOR GROUP A

GROUP A: DEALERS THAT IN SEPTEMBER HAD NEW TRUCK AND BUS TIRES, BUT FEWER THAN 40 { NEW PASSENGER TIRES; USED TRUCK AND BUS TIRES; USED PASSENGER TIRES }

μ_i and σ_i were estimated from a subsample of about 100 returns taken systematically from each size-class

No. of new truck and bus tires in Sept.	NEW TRUCK AND BUS						NEW PASSENGER					
	September			*December*			*September*			*December*		
	μ	σ	σ/μ	μ	σ	σ/μ	μ	σ	σ/μ	μ	σ	σ/μ
1– 9	3.5	2.3	.66	4.1	5.9	1.44	8.9	9.3	1.04	14.8	18.2	1.23
10–19	13.5	2.7	.20	13.0	9.6	.74	11.1	10.6	.95	21.0	26.3	1.25
20–29	24.1	2.8	.12	25.0	13.2	.53	13.6	11.2	.82	34.2	40.6	1.19
30–39	34.0	2.5	.07	38.2	17.9	.47	18.5	12.1	.65	34.2	28.2	.82

Remarks regarding assumptions. Three remarks are appropriate here. The most efficient use (optimum allocation) of a given number of questionnaires only requires that the *ratios* $\sigma_1:\sigma_2$, etc. between the standard deviations σ_i be assigned, and not their absolute magnitudes. Now very often one can make good guesses at these ratios even though the value assigned to each σ_i is too high or too low. Of course, if one consistently

assigns too high a value to every σ_i, and computes the size of sample required to give the precision aimed at, the precision actually attained will be needlessly high, which is not desirable as it entails a heavier burden of response and heavier cost than was actually necessary. On the other hand, if one consistently assigns too low a value to each σ_i, the precision actually attained will not be as good as the precision aimed at, though it may nevertheless be good enough. In the second place, it is a fact that the efficiency of the sample (as measured by the inverse of $\sigma_{\bar{x}}^2$) is only feebly altered by moderate departures from the optimum ratios between n_1, n_2, etc., as given by Eq. 8, wherefore a sampling plan may still be very efficient even if some of the assumptions and approximations are crude.

In the third place, regardless of what assumptions and approximations were made, or why, there need be no guess-work in the final results, because an analysis of the returns will show what precision was actually attained (cf. Part V).

TABLE II

COEFFICIENTS OF VARIATION FOR SEPTEMBER AND DECEMBER FOR GROUP B

GROUP B: DEALERS WITHOUT NEW TRUCK AND BUS TIRES IN SEPTEMBER BUT WITH FEWER THAN 40 {USED PASSENGER TIRES / USED TRUCK AND BUS TIRES}

μ_i and σ_i were estimated from a subsample of about 100 returns taken systematically from each size-class

No. of new passenger tires in September	NEW TRUCK AND BUS						NEW PASSENGER					
	September			*December*			*September*			*December*		
	μ	σ	σ/μ	μ	σ	σ/μ	μ	σ	σ/μ	μ	σ	σ/μ
0	—	—	—	.2	.9	4.5	—	—	—	1.0	3.6	3.60
1- 9	—	—	—	.5	1.8	3.6	4.0	2.4	.60	6.7	8.2	1.22
10-19	—	—	—	1.0	3.3	3.3	13.1	3.1	.24	13.0	9.9	.76
20-29	—	—	—	1.2	4.9	4.1	24.0	2.7	.11	24.7	11.4	.46
30-39	—	—	—	.8	2.7	3.4	33.9	2.9	.09	32.0	12.4	.39

Evaluation of k. To find k we note that Eq. 8 gives

$$\frac{\sigma_i^2}{n_i} = \frac{k\sigma_i}{N_i} \tag{15}$$

which when used in Eq. 13 shows that

$$\sigma_{\bar{x}}^2 = k\left\{\frac{\sigma_1}{\mu_1} N_1\mu_1\left(1-\frac{n_1}{N_1}\right) + \frac{\sigma_2}{\mu_2} N_2\mu_2\left(1-\frac{n_2}{N_2}\right) + \text{similar terms}\right\} \tag{16}$$

Now suppose that we restrict consideration to Groups A and B, fixing the aimed-at precision so that it should be attained from these two groups alone. The relatively small contributions of passenger tires from other groups of dealers (Part IV) will only slightly increase the precision. This procedure is not strictly optimum allocation over all strata, but is not far from it. One further simplification will be made; the finite multiplier $1-n_i/N_i$ in each term of Eq. 16 will be dropped (i.e., assumed to be near unity, as it would be if the sampling ratio n_i/N_i were small). Actually, the calculations for k (vide infra) should perhaps have been repeated to get a second approximation by retaining the finite multipliers in Eq. 16 with rough values of n_i/N_i. The coefficients of S_A and S_B in Eq. 17 would thereby have been decreased, but it was supposed that the effect was slight and not worth the effort. The next step, therefore, was to ignore the finite multipliers and factor out σ_i/μ_i for Groups A and B separately in Eq. 16 to find that

$$\begin{aligned}\sigma_S^2 &= k\left\{\left(\frac{\sigma}{\mu}\right)_A (N_1\mu_1 + N_2\mu_2 + \text{similar terms in Group A})\right. \\ &\qquad \left. + \left(\frac{\sigma}{\mu}\right)_B (N_1\mu_1 + N_2\mu_2 + \text{similar terms in Group B})\right\} \\ &= k\{2S_A + S_B\} \qquad (17)\end{aligned}$$

because $\sigma_i/\mu_i=(\sigma/\mu)_A=2$ for Group A and $\sigma_i/\mu_i=(\sigma/\mu)_B=1$ for Group B according to a previous decision (Eq. 14). It follows that the

$$(\text{C.V. } \hat{S})^2 = \frac{\sigma_S^2}{S^2} = k\,\frac{2S_A + S_B}{S^2} \qquad (18)$$

where C.V. $\hat{S}$ denotes the coefficient of variation of $\hat{S}$, or its standard error expressed in units of S itself. Solved for k this equation gives

$$k = \frac{S^2(\text{C.V. } \hat{S})^2}{2S_A + S_B}. \qquad (19)$$

It is now necessary to anticipate the division of the total number of tires S between Groups A and B. For simplicity it was assumed that the division in March would be what it was in December, viz.,

$$S_A : S_B = 8:1. \qquad (20)$$

Moreover, it was necessary to decide on a suitable value for S as of March '45, and after some deliberation it was decided that 1.8 million could not be far wrong. This number fixed the values of S_A and S_B as

1.6 and .2 million respectively, whereupon k could be obtained from Eq. 19 as soon as the aimed-at precision C.V. S was decided upon (next section).

TABLE III

SIZE OF SAMPLE FOR GROUP A

(Group A is defined in Table I)

No. of new truck and bus tires in Sept.	μ_i *For new passenger tires; assumed for March*	*Size of sample computed (Eq. 22)*	*Size of sample decided upon*	*Number of dealers in the* Universe N_i	Sample n_i
1– 9	15	15%	1 in 6	19,850	3,317
10–19	22	20	1 in 5	3,250	650
20–29	30	30	1 in 3	1,613	538
30–39	35	35			
40–49	45	45	1 in 2	894	447
50–59	55	55			
60 and over	—	100	all	1,662	1,662
			Total	27,269	6,275

TABLE IV

SIZE OF SAMPLE FOR GROUP B

(Group B is defined in Table II)

Number of new passenger tires in September	μ_i *For new passenger tires; assumed for March*	*Size of sample computed (Eq. 22)*	*Actual size of sample decided upon*	*Number of dealers in the* Universe N_i	Sample n_i
0	1	*½%	1 in 20	6,340	317
1– 9	7	3½	1 in 25	23,650	946
10–19	13	6½	1 in 12	6,500	542
20–29	25	12½	1 in 8	1,833	229
30–39	35	17½	1 in 5	1,136	227
40–49	45	22½			
50–69	60	30	1 in 3	358	119
70–99	85	42½	1 in 2	163	82
100 and over	—	100	all	168	168
			Total	40,148	2,630

* The sample decided upon was larger than computed for this size-class not only because its dispersion was much higher than the other size-classes (see Table II) but because this class of dealer is subject to more important relative shifts over time.

The aimed-at precision. It was decided that a coefficient of variation of 1.5 per cent would be desirable. This corresponds to a 3-sigma error-band of 4 or 4½ per cent outside of which errors of sampling practically never fall. This band of error seems to be small enough in view of the uses to be made of the data, and in view of other errors and biases that arise from difficulties in counting tires on hand and consigned.[6] Also

[6] An attempt at classifying a number of errors and biases was published by W. Edwards Deming in a paper entitled "On errors in surveys," *American Sociological Review*, vol. ix, 1944: pp. 359–69.

there was the stock of unknown magnitude held by unauthorized dealers. Altogether, further refinement of sampling error seemed out of place, because it would entail additional burden of response on the part of dealers, and increased costs to the government, and would moreover enhance liability to errors arising from nonresponse and other sources, most of which, as surveys are actually carried out, become more troublesome as the sample increases, and reach their maximum in attempts at complete counts.

With the aimed-at coefficient of variation of $\hat{S}$ set at 1.5 per cent, Eq. 19 gave

$$k = \frac{1.8^2 \times 10^{12} \times 1.5^2 \times 10^{-4}}{2 \times 1.6 \times 10^6 + .2 \times 10^6} = 214. \tag{21}$$

If the finite multipliers in Eq. 16 had not been neglected, k would have turned out to be a little greater than 214. Nevertheless, for ease in computation k was fixed at 200, whereupon from Eqs. 8 and 14

$$\left.\begin{aligned} \frac{n_i}{N_i} &= \mu_i \text{ directly in per cent for Group A} \\ &= \tfrac{1}{2}\mu_i \text{ directly in per cent for Group B} \end{aligned}\right\}. \tag{22}$$

And thus the sample was allocated in Groups A and B, which account for most of the new passenger tires (truck and bus also). Tables III and IV show the calculations and recommended sampling ratios.

IV. SPECIAL GROUPS OF DEALERS

The nonresponses of September. In September there were 24,015 questionnaires not returned, even after two "follow-up" notices. In December a 4 per cent sample of these names was drawn: in number this sample was 997. Here is what happened.

Number of questionnaires mailed out as a 4% sample of the September Nonresponses		997
Failed to return by mail and personal visit, or could not be located, or no personal follow-up made		310
Returned		687
Marked out of business	217	
Marked 0 passenger tires, or completely blank (interpreted as having no stock)	134	470
Reports showing 1 or more new passenger tires	336	

For March, a 5 per cent sample of the September nonresponses was recommended. The coefficient of variation (37.9/11.9 or nearly 3) of this group perhaps called for a slightly larger sample but it was deemed better not to risk overloading the district offices with this group (which was obviously inclined not to respond) and to accept a little larger sampling error at the gain of decreased bias of nonresponse.

For the 470 dealers returning blanks or 0 or 1 or more tires, the mean number of new passenger tires per dealer was 11.9, with a standard deviation of 37.9. When expanded by 25 this group gave

$$11.9 \times 470 \times 25 = 140{,}000 \text{ new passenger tires.}$$

This figure is to be interpreted as a minimum in the number of passenger tires held by the nonresponses of September because the 310 that failed to return likely also held tires. Anyhow, this minimum of 140,000 was a twelfth of all the new passenger tires in the hands of dealers in December and if these dealers held anything like the same stocks in September it is easy to see why there should have been discrepancies between the September complete count and the two quarterly samples in the preceding March and June (as was mentioned earlier). The ability of the staff of the district offices to call on the smaller number of delinquent dealers in a sample is responsible for the better response in December and March.

Blanks. In September, 29,133 dealers returned their questionnaires blank. A sample of 3 per cent of these was used in December, which when expanded on the basis of the returns accounted for 71,000 new passenger tires. One might conjecture that this group of dealers held enough tires in September to aggravate the trouble of balancing the books. A 3 per cent sample was recommended again for March.

New authorizations. There were 1,000 new authorizations between September and December and another 1,000 were allowed for over the interval between December and March. A sample of 200 was recommended as being adequate and easy to draw, being 10 per cent.

Manufacturers' outlets. There are about 2,000 manufacturers' outlets, averaging for September about 75 new passenger tires per dealer. A 100 per cent sample was recommended but a 1 in 2 or 1 in 4 sample might have been good enough because they were afterward observed to have fairly uniform stocks. No calculation of their coefficient of variation (σ/μ) was made.

Dealers holding in September 40 or more used tires of any kind but fewer than 40 new passenger or new truck or bus tires. A 25 per cent sample

was recommended: every 4th card starting with the 2d, first classifying the dealers in intervals of 10 tires (40–49, 50–59, etc.).

Motorcycle tires. Of the dealers reporting no new passenger tires and no new truck and bus tires in September, and fewer than 40 used passenger or truck and bus tires, 296 reported new motorcycle tires, and 91 reported used motorcycle tires. After inspecting the reports of these 387 dealers the sampling plan shown below was recommended:

No. of motorcycle tires in September	*Sample*
1–4	25% or 1 in 4
5–9	25% " "
10–14	25% " "
15–19	25% " "
20 and over	100% " all

Of course there were motorcycle tires held by other dealers, but stocks of motorcycle tires were well dispersed and the precision in this category should be good enough.

The contributions to the variance from these special groups was small because they were sampled adequately (approximately according to optimum allocation) and also because Groups A and B contained nine-tenths of the new passenger tires (and even more of the new truck and bus tires). In particular, the manufacturers' outlets, like the dealers with heavy stocks in Groups A and B, contributed no variance, being sampled 100 per cent.

Size of sample—all groups. The over-all sample from all groups, as calculated, turned out to be 14,750 dealers, which would have been about 1 dealer in 10. However, partly by mistaken carry-over of instructions from previous samples, and partly to gain simplicity in operation, bigger samples than specified were taken out of some of the special classes and the actual number of questionnaires mailed out was close to 16,000. As mentioned earlier, the response from the March sample (with two follow-up letters) was 96.1 per cent, and this sample included a 5 per cent sample of the dealers that did not respond in September.

V. RESULTS. COMPARISON OF THE PRECISION ATTAINED WITH THE PRECISION AIMED AT

The precision attained. The effect of stratification. After the returns were in, a subsample of about 100 cases was drawn systematically from every group for the purpose of estimating σ_i and μ_i for use in Eq. 13 whence the precision of the results was obtained. For comparison, the coefficients of variation were also computed for the precision as it would

have been if no stratification had been introduced. In both investigations the assumption was made that the equations of random sampling can be applied to estimate the precisions of our systematic samples, as in Remark 3. The apparent coincidence between the precision aimed at for the new passenger tires (1.5 per cent) and the precision actually attained (again 1.5 per cent), is partly an illusion, because the precision aimed at applies strictly only to Groups A and B, whereas the precision actually attained and shown in the table was computed for all groups combined. However, as was explained earlier, it was known that the contributions from the other groups could not have much effect on the over-all precision, so it can be concluded from the table that the agreement was excellent—unfortunately too good for illustrative purposes. The outcome does nevertheless show qualitatively the kind of results that will be obtained from plans that are drawn up with reasonable care, even though some of the assumptions and simplifications that one is forced to make often appear crude at the time. In this connection it should be borne in mind, too, that in practice it is never important to hit the aimed-at precision very closely, but it is important to learn from the returns what the precision actually was. This can usually be done at a small investment, and should never be omitted. A further advantage of studying the returns is increased knowledge and experience to be applied in future samples.

The precision for the new truck and bus tires (1.4 per cent; see Table V) turned out to be entirely satisfactory, as was expected, even though the criterion for fixing k and hence for fixing the size of the sample was based on new passenger tires. The reason is that the truck and bus tires were heavily concentrated in Group A.

TABLE V

ACTUAL COEFFICIENTS OF VARIATION ATTAINED OVER ALL DEALERS

Plan	*New truck and bus tires*	*New passenger tires*
Stratified with optimum allocation	1.4 per cent	1.5 per cent
Unstratified (for comparison)	4.4	2.5

Interpretation of sampling error. The observed coefficient of variation, measured after the returns are in, tells us that the number of new passenger tires held by dealers on March 31st, as determined by the sample, can hardly differ from the results of a "complete count" by more than $4\frac{1}{2}$ per cent (three coefficients of variation). The error band for truck and bus tires happens to be about the same width or smaller. But to

interpret these error bands it must be understood that the theoretical complete count with which the sample is compared must be taken with the same thoroughness as the sample, including pressure on the non-responses. Moreover, the complete count must cover the same universe of dealers, and not include (e.g.) unauthorized dealers. Thus, while the sample contains sampling errors, and is therefore less precise than a complete count, it is undoubtedly more accurate than a complete count would have been in practice.

VI. NOTE IN REGARD TO STRATIFICATION AND CONSERVATION OF INFORMATION FROM COMPLETE COUNTS

It is obvious from Table V that the stratification based on the complete count of September increased the efficiency of sampling enormously, even though considerable dispersion of inventories took place between September and December, and still more between December and March. Unstratified, the required sample for new passenger tires would have been $2\frac{1}{2}$ times as large; and for the new truck and bus tires it would have been 5 times as large. It should be explained that the gains in efficiency attributed here to stratification were actually the gains of stratification with optimum allocation. The gains that would have been made by stratification with proportionate sampling would not have been as great—perhaps two-thirds as great in this survey.

This experience seems to be typical in many sample surveys and teaches an important lesson in regard to conserving whatever information is available concerning the universe. Thus, the 1940 Census of Population providing statistics by blocks, tracts, and city size groups, even though now out of date in many spots because of heavy population shifts is nevertheless still effective for purposes of stratification, even for sampling blocks within cities, as experience and theory demonstrate. Similar remarks hold for the 1939 Census of Business. Some of the reasons are found in the section entitled "Remarks regarding assumptions." For example, optimum allocation will indeed be obtained even though the census or latest available complete count only indicates relative sizes (of firms, blocks, farms, etc.) and is entirely wrong on absolute values. But this is not all; a complete count, although out of date, will often go a long way toward segregating areas that may have suffered important changes, and which by the principle of optimum allocation should be sampled in higher proportion. Thus, in the footnote to Table IV it is explained that the O-class was sampled heavier than was indicated by the rule that was used for the other classes. Similarly, in the sample censuses of certain congested cities

taken in the spring of 1944, the blocks were stratified into classes according to the number of dwelling units in 1940, and every n-th block taken out for the sample. But the "O-blocks" (those that had no dwelling units in 1940) were thrown into a separate class for special investigation as a safeguard against the enormous changes that can take place when a large housing development goes up on land not previously occupied. Another illustration of the conservation of available information is found in the best practice in sampling in industry, wherein the lot, shipment, shift, or even order of receipt, are usually effective for subgrouping even though it may appear that the product must have become thoroughly mixed following production. It never is thoroughly mixed unless there has been a deliberate and skillful attempt to mix it.

It is not to be inferred that promiscuous stratification will get results. After the main assignable causes of variability have been removed through stratification, further stratification may avail too little to repay the cost.

It is a pleasure for the authors to record their indebtedness to Messrs. Morris H. Hansen and William N. Hurwitz for their early work with the authors on the design of the sample as it was first used for the tire inventory. It is a pleasure also to record the splendid cooperation of Messrs. S. Schotland and M. E. Robbins who were in charge of the Inventory and Control Branch of the Office of Price Administration in New York, where the samples were drawn and tabulated. Valuable professional assistance was rendered throughout the work by Dorothy Gottfried and Miss Sylvia Wolosoff of the New York Branch.

WAR-TIME ALUMINUM STATISTICS*

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THE START of the national defense program in 1940 found the United States government with few weapons and, at least in the case of aluminum,[1] little knowledge of the raw materials required to make those we needed. Moreover, the government had virtually no information to show the extent to which the United States possessed fabricating capacity to fulfill whatever the material requirements might be. Before the war, the Bureau of Mines collected annual data on virgin aluminum production and secondary recovery (from scrap), and the Department of Commerce tabulated our imports and exports, but that was about all. The lack of a comprehensive governmental statistical program for the aluminum industry coupled with the absence of a trade association program that might have served as a temporary substitute meant not only that new statistical surveys had to be conceived, put into operation, and refined, but also that appropriate research techniques and methods of analysis had to be worked out. The development of these techniques and methods under the uncompromising pressure of the war will be the major theme of this presentation.

The fact that in 1940 the Aluminum Company of America (Alcoa) was the only producer of virgin aluminum as well as the principal manufacturer of aluminum semifabricated products facilitated the task of obtaining the information needed to begin the business of national defense planning. Even with this central source of information the task was far from a painless one, and it was not until well into 1942 that lack of adequate aluminum statistics ceased to be a major source of difficulty in the work of the War Production Board (WPB). Although a comprehensive statistical reporting system was instituted by the

* The opinions expressed are those of the author and are not necessarily representative of the official views of the War Production Board, with which the author was associated, or of the Reconstruction Finance Corporation.

[1] *Aluminum* is used as a generic term to apply to all of the products of the aluminum industry, whether made of commercially pure aluminum or aluminum-base alloy and whether semi-fabricated or unfabricated. *Aluminum metal*, *aluminum pig*, and *aluminum ingot* are often used interchangeably to represent unfabricated metal. *Pig* is better used, however, to denote a crude form of unfabricated metal which, when refined and cast in a special form for subsequent use, becomes an *ingot*. *Virgin* metal (sometimes referred to as *primary*) is aluminum made from alumina, while *remelt* metal (commonly called *secondary*) is aluminum made from scrap. Some authorities use the term *secondary* to apply only to aluminum made from scrap whose original alloy identity has been lost, but this is a fairly restricted use of the term. Either *semi-fabricated products*, *aluminum products*, or *fabricated products* can be employed to represent the products of the industry which have been processed into desired alloy compositions, forms, and shapes; for example, sand castings, sheet, foil, extrusions, powder. In this paper *finished products* and *end products* will denote manufactures, such as aircraft and cooking utensils, made in whole or in part from aluminum semi-fabricated products. The United States could use a glossary of standardized aluminum terminology.

Office of Production Management, WPB's immediate predecessor, before Pearl Harbor, there was no substitute for background data and no telescoping the time for trends to make themselves known. Further, the aluminum industry proved to be far from a simple organism that revealed all of its structure and function under cursory examination. And it was found that the accounting and production planning departments of big business are not so flexible that they can readily conform to governmental reporting requirements that must be tailored to fit also the potentialities of some 1500 small aluminum establishments.

INDUSTRY STRUCTURE AND COMMODITY CLASSIFICATION

The activities of WPB in channeling the flow of materials, scheduling production, and guiding the operations of industry generally required, for administrative even if not for statistical considerations, the careful definition of the commodities and industries under the cognizance of each of the Board's separate organizational units. Because of the preponderance of the productive capacity encompassed by Alcoa and the Reynolds Metals Company and the close integration of operations within each company, it was natural to define the aluminum industry so as to make it coincide as far as possible with the boundaries of the activities of its two principal members. At the same time the production and accounting practices of the smaller producers had to be taken into account.

This approach proved on the whole to be satisfactory for both administrative and statistical purposes and brought the aluminum products and facilities shown in Figure 1 within the definition of the industry. Alcoa produced all the products included; Reynolds, most of them. A limited number of products made by Alcoa or Reynolds either were too widely manufactured and distributed as finished products or were too difficult to control as aluminum products to be included; for example, screw machine products, collapsible tubes, so-called Hooker tubing, processed foils (laminated, printed, embossed), and stampings. Empirical judgment would indicate that rivets, cable, and pigment-type powders, all of which resemble finished components as much as semi-fabricated products, might also have been excluded from the definition. Distributors of aluminum products and dealers in aluminum scrap completed the industry's coverage.[2]

[2] The mining and beneficiation of bauxite (the only mineral commercially used as a source of aluminum) and the production of alumina (aluminum oxide, extracted from bauxite and reduced to aluminum electrolytically) could be included as part of the industry under a general definition, but non-metallic materials such as these, so far removed from munitions production, were subjected to their own distribution and control techniques in the Board.

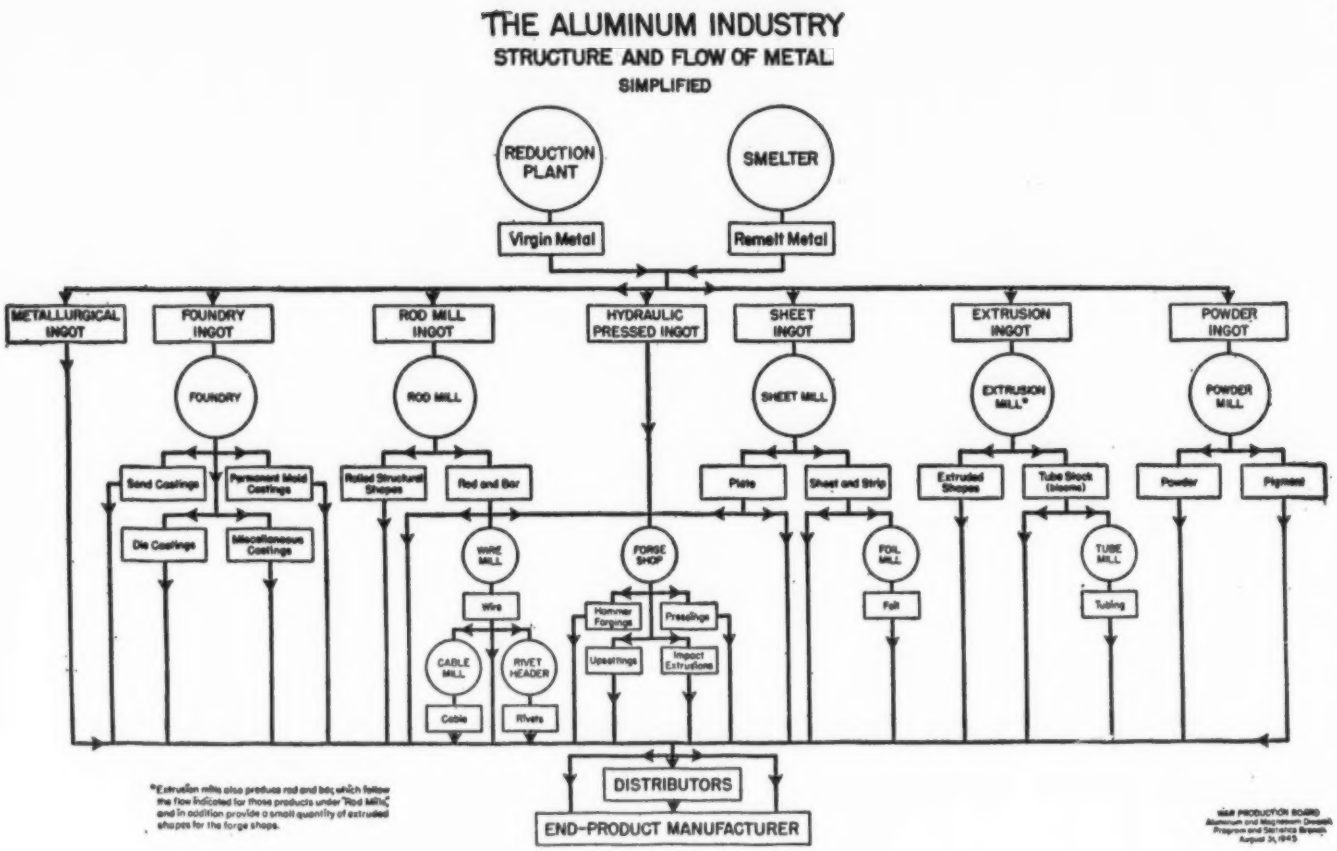
THE ALUMINUM INDUSTRY
STRUCTURE AND FLOW OF METAL
SIMPLIFIED
REDUCTION PLANT
SMELTER
Virgin Metal
Remelt Metal
METALLURGICAL INGOT
FOUNDRY INGOT
ROD MILL INGOT
HYDRAULIC PRESSED INGOT
SHEET INGOT
EXTRUSION INGOT
POWDER INGOT
FOUNDRY
ROD MILL
SHEET MILL
EXTRUSION MILL*
POWDER MILL
Sand Castings
Permanent Mold Castings
Die Castings
Miscellaneous Castings
Rolled Structural Shapes
Rod and Bar
Plate
Sheet and Strip
Extruded Shapes
Tube Stock (blooms)
Powder
Pigment
WIRE MILL
FORGE SHOP
FOIL MILL
TUBE MILL
Wire
Foil
Tubing
Hammer Forgings
Press Forgings
CABLE MILL
RIVET HEADER
Upsettings
Impact Extrusions
Cable
Rivets
DISTRIBUTORS
END-PRODUCT MANUFACTURER
*Extrusion mills also produce rod and bar, which follow the flow indicated for those products under "Rod Mills," and in addition provide a small quantity of extruded shapes for the forge shops.

FIGURE 1

While Figure 1 indicates the principal headings under which aluminum products can be classified, it does not reveal the detail to which useful classification could be and was refined in the administration of the aluminum program. It is almost a truism to say that the greater the detail available on requirements and supplies the better they can be matched. For instance, early in the war rod of small diameter became critical, but without knowledge of capacity, production, and requirements according to diameter, it was difficult to plan for the relief of the shortage. Moreover, plant capacities were determined to a great extent by the alloys and other specifications called for by consumers. The capacity of an extrusion plant is much greater poundage-wise when working on heavy or soft alloy sections than when producing light or hard alloy sections; and the capacity of a foundry falls when specifications are so rigid that ordinary practices of repairing defects in castings are outlawed.

The decision as to the aluminum classification scheme to be used by WPB in the operation of the Controlled Materials Plan—the plan which governed the distribution of aluminum, steel, and copper from 1943—became a contest with the statisticians and supply planners on one side and the administrators of the overall plan on the other. The former wanted a detailed classification broken down by alloy, size, and heat treatment; the latter were fearful that a detailed classification would unduly burden industry with paper-work and cause the plan to become enmeshed in "red-tape" and break down. The result, as might be expected, was a compromise. Instead of over seventy categories of aluminum—the maximum number ever proposed—it was agreed that bills of materials (the ultimate source of requirements data) would be prepared by industry on the basis of a thirty-three-item classification, that requirements would be calculated and submitted by the procuring agencies on the basis of a more consolidated list to vary according to the agency, and that allotments would be issued in eight categories.[3] The eight categories were also used for the public release of aluminum shipment statistics by WPB in the *Facts for Industry* series.

The limitations imposed with respect to allotment control and requirements data did not extend to the collection of statistics on the operations of the aluminum industry. Accordingly, throughout the war, data on aluminum production, shipments, and past-due unfilled orders

[3] The eight categories used for aluminum allotments compare with two in steel and six in copper. As experience was gained, the aluminum classifications were condensed until requirements were presented in eight categories and allotments were issued in one. The aircraft industry, by far the principal consumer of aluminum, was subjected for some time to more detail than other consumers, however, both in terms of requirements calculation and allotment accounting.

were collected in more detail than the eight categories, for it was found that analysis of shipments in terms of alloys, sizes, and heat treatments revealed significant trends in the pattern of business[4] that were invaluable in laying out production and facility expansion programs. In a sense, detailed statistical reporting and analysis of the past became a substitute for detailed controls over the future. As aluminum became easier in supply a good deal of this detail was dispensed with and the reporting job of industry was reduced as much as possible. The number of reporting categories was gradually condensed from forty-two to thirty-one.[5]

REQUIREMENTS DEVELOPMENT AND ANALYSIS

The fulfillment of the requirements of the armed forces, the foreign nations entitled to Lend-Lease assistance, and the war-supporting domestic economy for materials and finished products constituted the core of the responsibility of WPB. The Board delegated the responsibility for the compilation of requirements to the so-called "claimant agencies"—the War and Navy Departments, the Foreign Economic Administration, the Office of Defense Transportation, the National Housing Administration, the Petroleum Administration for War, and the other Federal agencies under whose cognizance the economic potential of the country was mobilized. WPB assumed the representation of those industries which produced components of such wide usage that they could not be handled by any one of the other agencies. The WPB Office of Civilian Requirements represented the civilian population.

Under CMP, the calculation of requirements began with the placement of a prime contract for an end-product, bearing specifications in terms of materials, performance, or both. The prime contractor prepared a bill of materials showing the amount of copper, aluminum, and other commodities, in designated shapes and sizes, required to produce a unit of the end-product, making appropriate allowances for scrap losses, spoilage, and spare parts. (A bill of materials was also prepared in some circumstances by the subcontractor and was submitted to the prime contractor for incorporation in his bill of materials.) The summary bill of materials was transmitted by the prime contractor to his claimant agency, where it became one of the many used in calculating

[4] The phrase *pattern of business* is used to represent the composition of the requirements according to the sizes, gauges, alloys, heat treatments, finishes, tolerances, and other specifications called for.

[5] The aluminum section of the U. S. Standard Commodity Classification departs in many respects from the scheme used by WPB, but the two can be brought together on a broad base.

the materials required for that agency's aggregate of procurement programs. The claimant agency compiled the material requirements for all its programs, taking into account the lead-time (length of manufacturing cycle) for each end-product and the expected change in contractors' unprocessed and in-process stocks, and submitted the resulting figures to WPB. The requirements were submitted quarterly and included not only the data for the one quarter under immediate consideration, but also for as many as five additional quarters.

The Board, with a staff of economists, statisticians, and industrial specialists, analyzed or "screened" the requirements submitted by each claimant to determine initially whether the requirements were reasonable representations, in terms of materials, of the agency's procurement programs. When total screened requirements exceeded available supplies, the Board had to investigate the conflicting demands, weigh the consequences of alternative program reductions on each of the armed forces, on the civilian economy, and on the Lend-Lease recipients, and decide how the available supplies should be allocated. On some occasions, when the competition for materials was finally narrowed to the armed services, the question as to the programs to be cut back was referred to the Joint Chiefs of Staff or the Under Secretary of War. The final decision of the Board was embodied in formal allotments of each commodity, issued by the Chairman of the WPB Requirements Committee to the various claimants.

This lengthy chain of events had a marked effect on bringing material requirements out of the chaos in which the beginning of the war found them. That is not to say, however, that the requirements were wholly accurate descriptions of the materials really needed. Figures on aluminum, for example, show that for nearly every quarter of the operation of CMP, shipments were substantially below originally stated requirements and allotments, and yet past-due unfilled orders showed no substantial change. It is evident that requirements were usually inflated. There are many reasons why this was so, and a few will be enumerated.

1. There were numerous changes in production schedules for end-products made between the time the requirements were calculated and the quarter to which they were applicable. After 1942 these schedule revisions were usually decreases, rather than increases.

2. Spare parts requirements were usually calculated very generously to allow for high combat losses and damage. Experience has shown that these allowances were too high.

3. Scrap losses were actually lower than manufacturers calculated them to be, probably because of the increased skill and efficiency achieved in manufacturing operations.

4. Shortages of components caused industry to fall behind production schedules for end-products, and thus the aluminum which would have been required had the components been available was not ordered.

5. The human tendency to ask for just a little more than the minimum necessary, either for the sake of safety or for the sake of negotiation, was undoubtedly present, although it must be said in all fairness to the claimants that conscientious conservatism over-shadowed any apparent inflation of requirements for bargaining purposes.

Even if the claimants had been most successful in calculating their requirements, there undoubtedly would have been a small amount of attrition[6] caused by the administrative operations of CMP. The transfer of allotment papers through so many hands and the tendency to establish small reserves of allotments at each link in the chain would have, of itself, prevented the total use of allotments issued. Allotment paper followed the reverse course of requirements paper and passed from WPB to the claimant agency, to the prime contractor, to the subcontractor, and to the most remote sub-subcontractor, down the line. Attrition was recognized early as a concomitant of CMP and was compensated for by allotting a small excess over available supply.

The procedures and techniques used by the claimant agencies in their operations will make an important narrative that should be preserved for a future emergency. Perhaps the Army and the Navy will continue to calculate material requirements in the same way for peace-time programs, thus preserving a skeleton of their war-time materials planning organization. Although the ideal method of compiling requirements was described above, each claimant agency worked out modifications and devised substitutes for the bill of material procedure to meet its own circumstances.

EVALUATING CAPACITY AND FORECASTING PRODUCTION

One problem that defied complete solution and became a recurring source of difficulty in aluminum, and apparently in other materials planning was the determination of capacity. Perhaps no other aspect of WPB operations was featured by so much confused thinking and misunderstanding. Part of the explanation for this lies in the use of an unorganized system of nomenclature. The many terms used in this

[6] *Attrition* is a shop term denoting the difference between requirements, allotments, and orders placed.

field were never carefully defined and thus became crude tools of expression, vague in intent, implication, and interpretation. The use of different terms to represent the same thing and of the same term to represent different things is symptomatic of an effort to find a short-cut through a complicated subject but there is probably no short-cut to be found. We must recognize that in capacity studies, as in other statistical work, statistics are meaningful to the extent that (i) they are developed to serve a specific purpose, (ii) the assumptions on which they are based are clearly understood by both the statistician and his audience, and (iii) their probable error can be determined.

Capacity studies served two principal purposes in aluminum planning: first, to determine the need for building new plants to meet requirements on a long-range basis; second, to determine how much material could be produced in the facilities in operation to meet requirements on a short-range basis. In each case a plant-by-plant study was essential; indeed, for some commodities the study of the potentialities of each piece of operating equipment within a plant was called for. In studies initiated for long-range planning purposes the answer to this question was sought: How many pounds of commodity X can the aluminum industry produce monthly at peak with the pattern of business that can be forecast and with its present plants and the additional facilities already authorized or under construction, if there are no limitations on available manpower, production materials, maintenance, repair, and operating supplies, transportation facilities, and power? All the factors of production, in other words, are assumed to be at their optimum; the unknowns are the pattern of business inherent in the requirements and the potentialities of the physical production facilities in the light of the pattern. The reason for posing the question in this form is not obscure. There was no point in building new facilities if those in existence or already planned could, under the proper conditions, produce the amount of material required. If a shortage of labor, for example, were anticipated as a limiting factor in production, it had to be remedied directly. New facilities required so much construction time and critical materials that they could not be authorized if any other method of increasing production could be found.

The short-range study posed a different question: How many pounds of commodity X can the aluminum industry produce in a given quarter with the pattern of business and under the operating limitations with regard to manpower, raw materials, etc. that can be forecast for the quarter? (*Maximum practicable production* is the most descriptive term to represent this concept.) This question was easier to answer in some

respects, and more difficult in others, than the long-range question of supply—easier because it had to be answered only two or three months in advance of the quarter under consideration, but more difficult because of the many variables to be taken into account that were not susceptible of statistical treatment. The principal unknown was manpower. What urgency rating would the industry be granted for each of its plants? How effective would the rating be in increasing recruitment of labor by the United States Employment Service? Would interregional recruitment be permitted by the War Manpower Commission? What would be the impact of changes in Selective Service regulations? Would the Army furlough soldiers to work in the plants? Would the War Labor Board approve a pending wage increase? Would the National Housing Administration obtain needed trailer-housing in time? Would the Manhattan Project on one side of Knoxville continue to compete with the aluminum sheet mill on the other side? To what extent would seasonal factors affect labor supply? And how could the answers to all of these questions, if obtained, be translated into an estimate of manpower on the job and producing aluminum?

After the manpower uncertainties were resolved as far as they could be, the next point of investigation was the rate at which the industry could accelerate its production from the level at which it was expected to be operating immediately prior to the beginning of the quarter. Fluctuations in the demand for aluminum products were very marked during the last two years of the war, not only because of changes in procurement programs for end-products but also because of changes in the inventory policy of the aircraft industry. The year-end inventory clean-up drives of aircraft manufacturers caused aluminum orders and mill schedules to shrink in the last quarter of the year and rise again in the first quarter. This was particularly apparent at the end of 1944, before the reverses in the Ardenes, when the aircraft industry, with one eye on the headlines and the other on aircraft cutbacks, lived off their stocks and kept new orders at a minimum. In the face of such fluctuations in demand, the calculation of maximum practicable production for a quarter following one in which the mills were producing at relatively low levels, had to be tempered by the knowledge that building up maximum speed in an industrial plant was a gradual process. New workers, assuming that they could be hired, had to be trained and had to develop skills on the job, production lines had to be extended, new shifts established, working stocks built up, and so on.

The gathering of data for capacity studies was a joint task of the WPB production specialists and the statistical-planner. It was mani-

festly impossible for the latter (or his staff) to do the job without technical consultation. The statistician, however, laid down the ground rules so that uniformity would be achieved by the many people contributing to the task. The production specialists studied plant records, often visited the plants themselves, conferred with the producers, contacted other government agencies, and submitted a preliminary report. The statistician coordinated the data contained in all the reports filed, analyzed them in terms of past performance in comparable periods, brought to bear the manpower data available, and reported his recommendations to the executive in charge of the whole aluminum supply program. The commitments on supply were then made, usually after a final conference with the production specialists and the statistician.

The concept of maximum practicable production was not infrequently confused with *estimated production*. For example, one researcher proposed to measure the reliability of supply forecasts by comparing quarterly CMP supply commitments—the equivalent of maximum practicable production—with actual shipments. The results of such a comparison would be meaningless, for one variable that maximum practicable production figures did not take into account was the amount of orders that would be placed on the mills. Obviously the mills would not ship more than their customers ordered, with the possible exception of relatively small amounts preshipped against orders for delivery in future periods. The forecast of production (or shipments) as distinguished from maximum practicable production thus required a further leavening of the capacity concept by the introduction of another variable—order placement. Such forecasts were prepared by analyzing the requirements for a commodity and deflating or occasionally inflating them to realistic quantities to represent estimated order placement. When this figure was substantially lower than the maximum practicable production forecast, and it usually was, it was used to represent estimated production. Reports by industry of order acceptances for future months, while not a complete representation of the actual production load to be handled for more than one or two months ahead, were also of value in developing estimates of order placement.

The nature of the task of developing capacity and production estimates varied, of course, from product to product. Virgin aluminum is produced by an electrolytic process that requires continuous operation. Thus, the question of the number of shifts to be in operation during a period did not enter: a plant unit either operated full-time or it stopped operating. The pattern of business was not a factor; slight variations

may occur because of the changing needs to produce "rich alloys" in the reduction cells or pots, but the effect of this is negligible. A small slump usually occurs in the summer months, but otherwise, excluding curtailments caused by policy decisions or severe labor or power shortages, production is very stable. Secondary metal is in a class by itself. While the calculation of smelter capacity and maximum practicable production present no unusual problems, the forecast of smelter production and of net secondary recovery is a complicated affair in which the element of the informed guess must enter strongly. Smelter production is influenced by the relative prices of primary ingot, secondary ingot, and aluminum scrap, with the latter being particularly subject to rapid market fluctuations. The policies of integrated producers which use large quantities of scrap also influence secondary recovery substantially. The manufacture of semi-fabricated products is subject to all possible influences, including the pattern of business, the number of shifts that can be operated, the heat of operation in the summer (notably in foundry work) as well as labor supply, the supply of fuel for heating melting furnaces, and the like.

THE CONCEPT OF "NET SHIPMENTS"

Aluminum may pass through several stages of fabrication and through the hands of a distributor before it is shipped out of the industry to the industrial consumer.[7] In this respect aluminum is no different from other metals which serve structural purposes. While ingot shipments might be used as the basis for a statistical system in aluminum, such a measure, only indirectly responsive to changes in industrial demand, would be of limited value. Measuring aluminum activity at the semi-fabricated product level is much to be preferred, although it involves several problems in surveying the industry and interpreting the tabulated data.

It is plain that if we were to add together shipments made by all plants in the industry our total would be inflated to the extent that the same metal is counted as a shipment more than once. Rivets shipped by a distributor to a cooking utensil manufacturer, to take an extreme case, would be counted as ingot, rod, wire, and rivets. And if distributors were included in the system, the rivets would be counted twice as rivets: once when shipped by the rivet manufacturer to the distributor and once when shipped by the distributor to the final consumer. It was apparent at the start of planning the aluminum program that, while it

[7] A relatively small amount of aluminum is used outside of the aluminum industry as ingot; for example, in deoxidizing steel and alloying magnesium.

was essential to know how much of each aluminum product was produced and shipped, regardless of use, it was no less essential to know how much aluminum was being obtained by military contractors and other consumers. Neither gross nor net figures could be dispensed with.

The problem of calculating net shipments was solved by assigning each producer and distributor in the industry with an identification number which he was required to endorse on the aluminum orders he placed with other producers or distributors. This requirement was applicable also to the separate departments of the integrated producers, each department being treated as a separate unit. With this sort of identification on orders received, it was possible for each aluminum supplier to report his shipments divided among shipments to other producers (called shipments for further fabrication), shipments to distributors, and shipments to ultimate consumers. The assignment of identification numbers was arranged schematically so that each number not only indicated that the enterprise using it was in the aluminum industry but also distinguished a producer from a distributor and, in the case of a producer, defined the type of aluminum product he would fabricate from the aluminum product shipped to him.[8] A technique somewhat similar to this was used by WPB during the war for the steel industry. Steel used a uniform symbol rather than an individual number, however, and did not include in gross shipments, transfers of material among the separate departments of an integrated company.

INDUSTRY STOCKS AND THE "PIPELINE"

Closely allied with concept of net shipments is the concept of "pipeline." The pipeline of the aluminum industry may be defined as the amount of ingot, in-process metal, and semi-fabricated products held by, and material in transit to, plants in the industry that is required to enable the industry to ship its products at a given level. A brief equivalent might be "minimum working stocks."

It is a happy coincidence that the processing losses encountered in converting aluminum pig to semi-fabricated products closely approximate the weight of ingredients (copper, magnesium, chromium, etc.) added in the production of aluminum-base alloys. Thus the net change in the industry's total working stocks during a period can be estimated within narrow limits by subtracting net shipments of aluminum products from new supply (virgin metal production, net secondary recovery,

[8] This method of identification proved particularly valuable as it provided WPB with the data for determining the quantity of one aluminum product required to produce a unit of another; for instance, the quantity of tube blooms required per pound of tubing. Reliable ratios of this kind were essential tools in all WPB metals research.

plus imports) for the period and making an appropriate adjustment for any change in government-owned stocks. This principle becomes more useful when it is combined with another, namely, that the industry requires two and eight-tenths to three pounds of aluminum in its pipeline to make *monthly* net shipments of one pound of aluminum products.

Once a base inventory figure was established it was possible, with these principles and without a series of inventory reports, to determine the stock position of the industry at the end of each month and particularly to observe the trend of industry stocks over a series of months. It was also possible to forecast with great facility the amount of metal that the industry itself would require for the pipeline (that is, over and above the amount to be shipped to consumers) to meet increased total requirements, and, conversely, the amount of metal that could be made available from the pipeline if requirements fell.

The following formulae will illustrate:

$$P_c = V + S_n + I - N + (G_b - G_e) \tag{1}$$

$$P_c = 2.8\,\frac{R_q - R_{q-1}}{3} \tag{2}$$

where

P_c = pipeline change
V = virgin metal production
S_n = net secondary recovery
I = imports
N = net shipments of aluminum products
G_b = government-owned stocks, beginning of period
G_e = government-owned stocks, end of period
R_q = requirements for a designated calendar quarter
R_{q-1} = requirements for the preceding calendar quarter

Data to solve these equations were available from reports filed by industry or government agencies. The change in the pipeline for a past period could be calculated through equation (1); the change in the pipeline for a future quarter could be forecast through (2).

From this discussion it might appear that it was assumed that the aluminum holdings of the industry were always at the minimum required levels and that the pipeline changes indicated by the preceding calculations would occur immediately. It was recognized, however, that changes in demand sometimes were too rapid and too extensive to permit the industry to adjust its stock position in a month or two. In addition, domestic virgin aluminum production could not be curtailed as

rapidly as requirements fell because of the possibility that subsequent increases would call for reopening facilities, a difficult accomplishment once the labor supply was absorbed by other industries. Since production curtailments generally lagged behind decreases in requirements and since the government did not purchase domestically-produced virgin aluminum for stockpile purposes, the producers of virgin metal carried for a substantial period of time much more metal than they required for their operations. The excess stocks held by the industry (E) were estimated in consultation with the producers, and while excess aluminum industry stocks existed, (1) became:

$$P_c = V + S_n + I - N + (G_b - G_e) + (E_b - E_e). \qquad (3)$$

It might also appear that the excess stocks of the industry could be determined from monthly net shipments data, as follows:

$$E = P - 2.8N \qquad (4)$$

where P represents the total pipeline calculated by adding the monthly pipeline increments to the base inventory. Reliance on this formula would have been tantamount to assuming that the processing losses *exactly* equalled alloying ingredients, for even a small monthly error over a period of several years would accumulate to large proportions. This assumption could not be made with confidence,[9] and accordingly other techniques were used to estimate the excess metal that existed at any time.

The usefulness of the pipeline formulae made it unnecessary to obtain monthly inventory reports from the whole aluminum industry. Regular inventory reports were obtained from the primary metal producers and the secondary smelters, but the rest of the industry was free of inventory reporting except when some problem requiring a knowledge of the location of specific products or alloys made special reports necessary.

SECONDARY METAL AND SCRAP

Secondary metal supply is another subject which had to be cut to the measure of war-time statistical requirements. Fortunately the pre-war surveys and analyses of the Bureau of Mines provided an excellent starting point for the WPB program in this field. The Bureau received

[9] In fact, a review of the monthly ratios of P/N showed a steady rise that could not be satisfactorily accounted for. This indicated a small monthly discrepancy cumulating over almost four years which inflated substantially the total amount calculated to be in the pipeline. This tendency to overstate the pipeline was not great enough, however, to impair the usefulness of the formulae for forecasting pipeline changes six or nine months ahead.

reports on all transfers of scrap *between companies*. The resulting recovery figures therefore encompassed new scrap generated in the aluminum industry, new scrap generated by finished product manufacturers, and old scrap;[10] they did not encompass new scrap that was used within the company in which it was generated. Thus, at least implicitly, the Bureau defined secondary recovery as metal recovered from scrap used in a company other than the one which generated it.

There is no argument that such a definition is satisfactory for ordinary purposes inasmuch as the commercial aspect of the secondary metals industry is as important as any other in peace-time. Nevertheless, an analysis of this approach in terms of the requisites of the wartime statistical program for aluminum showed that new principles had to be established, as follows:

> First: Secondary recovery data must *exclude* metal recovered from new scrap generated in the course of producing any semi-fabricated aluminum product within the defined scope of the aluminum industry, even if such scrap is sold by one company to another.
>
> Second: Secondary recovery data must *include* metal recovered by the aluminum industry from new scrap generated in the course of consuming (for example, machining) semi-fabricated aluminum products, even if the scrap is generated by a company which remelts such scrap itself and does not sell it to others.
>
> Third: Secondary recovery data must include all metal recovered by the aluminum industry from old scrap.

The first principle calls for the exclusion of certain types of scrap included by the Bureau of Mines, namely, scrap generated in the aluminum industry and sold by one company to another. The metal embodied in scrap of this type was never incorporated in a semi-fabricated product shipped by the industry. It was counted as an addition to supply when originally produced as virgin metal and cannot be counted again as secondary metal until it passes out of the industry as an item included in net shipments, and then returns. It must be remembered that the aluminum industry includes semi-fabricated product manufacturers as well as ingot makers and that the WPB balance sheet of the industry was designed to measure unfabricated supply on one side and semi-fabricated shipments on the other. All the metal between these two points of measurement constitutes the pipeline, and until metal leaves the pipeline it cannot be counted as an addition to supply in secondary form.

The second principle calls for the inclusion of certain types of scrap

[10] *Old scrap* is scrap obtained from obsolete, broken, or worn-out finished products, such as wrecked automobiles. *New scrap* is scrap generated in the course of manufacturing operations.

excluded by the Bureau of Mines, namely, scrap generated in the course of the ultimate consumption of semi-fabricated products but remelted by the company which generates it. Scrap of this type, transferred within a company which is integrated to the extent that it both produces and consumes aluminum products, is no different from scrap generated by a non-integrated consumer. To illustrate: Company A manufactures cooking utensils and the aluminum sheet from which they are made. Scrap generated in the cooking utensil department is sent to the sheet department for remelting and rerolling into sheet. The sheet is then sent back to the cooking utensil department for use. Company B manufactures cooking utensils exclusively, using sheet purchased from Company C. Scrap generated by B is shipped under a toll agreement to C for remelting and rerolling into sheet, which is then returned to B. Company D also manufactures cooking utensils exclusively, using sheet purchased from C. But scrap generated by D is sold to Company E, a smelter. Company E remelts the scrap and sells ingot to Company F, which rolls it into sheet for sale to Company G, an aircraft manufacturer. Treatment of the scrap in all these three cases must be the same in materials calculations. Although the scrap moves through three different channels on three different commercial bases—intra-company transfer, toll, and sale—the material movement and the contribution to supply in the form of secondary recovery are identical for the aluminum industry taken as a unit.

There is no difference between the WPB and Bureau of Mines secondary recovery calculations with respect to the third principle dealing with the treatment of old scrap. There is one other point of difference, however. The Bureau includes aluminum scrap used outside of the aluminum industry, for example, in the production of chemicals. Since WPB was comparing the supply available from, and the requirements placed on, the aluminum industry and since demands of other industries for aluminum scrap were not included in aluminum requirements calculations, the use of aluminum scrap outside of the aluminum industry was not included by WPB in the calculation of net secondary recovery.

The theoretical development of these principles was a much more simple task than their application to the collection of secondary metal statistics and the calculation of net secondary recovery. To achieve perfection it would have been virtually necessary to put a tag on each piece of scrap so that after it moved from generator, to dealer, to user, its identity could be determined and reported. Fortunately an analysis of aluminum production and scrap trade practices revealed that a re-

porting system, not markedly different from that used before the war by the Bureau of Mines, would provide the basic data which, when adjusted to eliminate double-counting of new scrap generated and sold within the aluminum industry, would give a secondary recovery figure representative of the net addition to the aluminum supply obtained from scrap.[11] The WPB calculation proceeded along the following lines. Recovery of scrap by smelters was calculated by adjusting their total ingot production figures to eliminate that portion of the ingot obtained from materials blended with the scrap (virgin metal, secondary pig, and alloying ingredients). The smelters figures were also adjusted to remove the amount recovered from scrap processed on toll. This type of scrap is usually generated by aluminum foundries; hence it is considered the equivalent of "run-around" scrap circulating within the industry even though sold by its generator. Scrap purchases of integrated producers of virgin metal, including scrap received from their end-product departments, less an estimated melt loss, were also included. Receipts, less estimated melt loss, rather than actual consumption and recovery, were used in this case primarily because of convenience in reporting. Scrap receipts of foundries and other producers of semi-fabricated products were included in similar fashion. From the total of these three items was subtracted the estimated quantity of scrap generated by producers of semi-fabricated products who did not have melting facilities, i.e. the producers who ship all of their scrap to others within the industry. This estimate was calculated by multiplying the reported shipments of semi-fabricated products made by these producers by factors obtained from industry experts representing the amount of scrap generated per pound of product manufactured. A formula summarizing the whole calculation would read as follows:

$$S_n = S_s + S_i + S_f - (.26F + .08R + .70T) \qquad (5)$$

where

S_s = secondary recovery by smelters, excluding recovery from their own "run-around" scrap and scrap processed on toll.

S_i = secondary recovery by integrated metal producers, including recovery from scrap generated in their own end-product departments, but excluding recovery from their own "run-around" scrap.

S_f = secondary recovery by producers of semi-fabricated products, including recovery from scrap generated in their own end-product department, but excluding recovery from their own "run-around" scrap.

[11] Scrap data were obtained from aluminum scrap dealers throughout the war and from aluminum smelters in 1945 by the Bureau of Mines as agent for WPB; smelters data prior to 1945 and other scrap data were obtained by WPB itself.

F = shipments of forgings by producers without melting facilities.
R = shipments of rivets by producers without melting facilities.
T = shipments of tubing by producers without melting facilities.

FOREIGN TRADE STATISTICS

Both for reasons of speed and convenience and because of the nature of the Controlled Materials Plan the data developed in WPB on aluminum imports and exports are noticeably different from those compiled by the Department of Commerce. The discrepancies over the period 1941–1945 taken in the aggregate should be negligible, however, for the differences are attributable principally to timing rather than method of measurement.

Beginning in 1941, the United States, through the Office of Metals Reserve, made a series of contracts calling for over a billion pounds of aluminum to be delivered by the Aluminum Company of Canada. Transactions under these contracts were entered into WPB import statistics as soon as the aluminum was delivered to warehouses in Canada for U. S. account or, in the case of metal sent directly to the U. S. by the producer, at the time it was shipped by rail. This method of calculation was used because U. S. holdings in Canada were included in U. S. stockpile figures, and the aluminum metal accounting system would have been out of balance otherwise. It should be noted that not all of the metal contractually delivered crossed (or will cross) the border. Some of it was resold to Canada, some was transferred to the account of the U. K. in repayment for loans of aluminum made to the U. S. early in the war, and some was sold to the U. K.

Imports of relatively small quantities of aluminum were also made under other special arrangements. The U. S. received aluminum semi-fabricated products of Canadian manufacture for which we provided the aluminum raw materials. On the other hand we received ingot from the U. K. in reimbursement for various aluminum semi-fabricated products which we provided through the Foreign Economic Administration and in reimbursement for aluminum powder provided through the Navy Department.

Reports of shipments filed by aluminum producers and distributors were used in compiling export data. As far as CMP was concerned the job of supplying a requirement was completed when the aluminum industry shipped the materials ordered out of its plants. Accordingly no regular effort was required or made to follow up mill and warehouse shipments to the point of actual export. WPB export data therefore reflect the time of mill shipment rather than the time of actual export.

These data include Lend-Lease shipments as well as shipments on direct sale; they do not include material purchased by the Army and Navy and destined ultimately for shipment for their own use abroad or for the use of a foreign country under the International Aid program. Department of Commerce figures are similarly compiled, except with respect to timing and except for International Aid shipments, which are included in the official foreign trade statistics.

* * *

The experience of the War Production Board has several significant implications for the future. It showed, if further proof were needed, that "descriptive" and "mathematical" statistics are indispensable tools not only of governmental but also of industrial administration and planning. It showed that the nation's springboard for total production is a detailed knowledge of the condition of its industrial machine and that the pre-war surveys of the Federal government were not good enough for this purpose. Finally, it showed that a successful governmental statistical program must be a coordinated program, molded by a constructive and central force. The consideration already given to the integration of Federal statistics[12] is a hopeful indication that the handwriting on the wall is being read by statisticians.

[12] See "Problems of Integrating Federal Statistics: A Round Table," *Jour. Amer. Stat. Assoc.*, Vol. 40, No. 230, June 1945, pp. 237–244.

HISTORICAL NOTE ON THE PURCHASING POWER CONCEPT, AND INDEX NUMBERS

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IN HIS historical appendix to *The Making of Index Numbers*, Irving Fisher credits to Dutot, in 1738, the construction of the first index number of prices, a simple aggregative. A few years ago I picked up in a second-hand book store in Columbia, S. C., a book published in London in 1707 in which the author computes a kind of mental weighted average of relatives index of retail price changes between 1440–1460 and 1686–1706. Whether the arithmetical application of the formula is sufficiently precise to give the author credit for the first index number is open to question, as will be seen, but there can be no doubt that he had a clear concept, not only of the purchasing power of money and its significance, but also of the principles of constructing both weighted aggregative and weighted average-of-relatives index numbers which the succeeding 240 years have only refined, not changed basically.

The title page does not disclose the name of the author, but bibliographers credit the book to William Fleetwood, the Bishop of Ely. The title page reads as follows: "*Chronicon Preciosum:* or, an ACCOUNT of ENGLISH MONEY, the PRICE of CORN, and *Other Commodities*, For the last 600 Years.—in a LETTER to a *Student* in the University of *Oxford*.—LONDON, Printed for Charles Harver, at the *Flower-de-luce*, over-against St. *Dunstan's* Church, in *Fleetstreet*. MDCCVII." Two reprints appeared in 1737 and 1745. The book has six chapters, one given to a statement of the problem, two to accounts of gold and silver coins, two to scattered quotations of commodity prices and wages "for 600 years last past," and a final chapter giving the conclusion. Present interest centers on the first and last chapters.

It is interesting to observe that a practical problem of morals gave rise to the speculations of the author—or did it really? One is led to wonder if the Bishop, having spent a good deal of time looking into the history of coins, prices and wages, did not invent a practical question as an expositional device—not a blame-worthy motive. Be that as it may, he also found a second and a third application of his theory in his Conclusion. Let the Bishop state the proposition, as submitted by the "student":

"CHAP. I.

"*The* CASE

"The Statutes of a certain College (to the Observation of which, every one is sworn, when admitted Fellow) vacating a Fellowship, if the Fellow has

an Estate in *Land of Inheritance*, or a *perpetual Pension*, of *Five Pounds per An.* I desire you would be pleased, to give me your Answer to these following Questions; when I have first told you, that the College was founded between the Years 1440, and 1460.

"I. Whether He who is possessed of an Estate, of that, or greater Value, may make it over *in trust* to his Friend, and then safely swear to the Observation of such Statute, amongst the rest?

"II. Whether He who has not an Estate of that Value, when admitted Fellow, may keep his Fellowship tho' he *afterwards* come to an Estate of that, or much greater Value?

"III. Whether He who is actually possessed of an Estate, of *Six Pounds per An.* as Money, and Things go *now*, may safely take that Oath, upon presumption, that VI *l.* now, is not worth what V *l.* was, when that Statute was made."

Bishop Fleetwood found no difficulty in coming to a negative answer on the first two questions. Only the third question disturbed the Bishop and interests us:

"Your *Third* and last Question will cost me more Pains, and you more Patience, before we come to the Conclusion; if we can come to any satisfactory one at last. The Question would certainly need no Answer, if it were asked in gross, *Whether he who has VI Pounds* per An. *may safely swear he has not V?* When a Pound is, in both Places (and has been so for more than 600 Years) XX *s.* but as you have qualified it, by distinguishing the Times, it will require both a good Casuist, and a pretty good Historian, to answer it absolutely, and to your Purpose; which is (as I take it) to know, of what Value you may now hold an Estate, with safety to your Conscience, which is charged with the Observation of that Statute, which vacates the Fellowship of One who has an Estate of Inheritance, or a perpetual Pension of C *s.* or V *l. per An.* A better Casuist, I own, you might easily have found. But, it may be, you could not so easily have found One, who hath in his Readings, made more Observations on the Price of Corn, and other Commodities, at different Times, than I have done, as you will perceive by reading this long Letter. So that, for ought I know, my Diligence may make you Amends for what want of Judgment may be found in me. And I do not say this in Vanity and Ostentation of my Labour, but because without a good share of Knowledge in these Matters, the best Casuist in the World can never answer your Question satisfactorily. . . . "

The Bishop need not have so disparaged his own "casuistry," for after a few remarks about the "good use, in the Consideration of great Affairs" that may come from "Collections of so mean Things, as the Price of Wheat, and Oats, of Poultry, and such like Provisions," he argues the case in a manner that would do credit to an Economic Statistician a century later.

"I do affirm then, with the best Judgment I have, that I am seriously persuaded, that, altho' you are actually possessed of an Estate of VI Pounds

per An. as Money and Things go now, you may safely take that Oath, upon Presumption that VI Pound *now*, is not worth what V *l.* was then, when that Statute was first made. Because whoever swears, swears to *Things* that are signified by Words, and not to *mere words*. When a Word signifies the same thing *now* in effect, which it signified 260 Years ago, then he who swears to *Words*, swears to the Things they signifie; but when different Things are signified by the same Word, then he who knows that difference of Things, cannot help giving such Word, its proper and intended signification. A *Pound* (for instance) will buy either more, or less Corn (take it which way you will) *now*, than it would in *H.* VI [Henry the Sixth's] time. A *Pound* is therefore of more or less Value *now*, than it was *then;* and the *Value* of a *Pound* is truly a *Pound*, and not its mere *Name*. It is not therefore the same *Thing* now, that it was in *H.* VI. time."

Have the succeeding 238 years brought a better statement of the concept of the purchasing power of money? The author even had a clear notion of a regimen of commodities to be used in a weighted aggregative index number:

"And that I may very honestly have Regard to the Value of V *l.* 260 Years ago, will, I believe, appear evident from what I am going to say; That the Founder intended the same Ease, and Favour to Those who should live in his College 260 Years after his Decease, as to Those who lived in his own Time. Now, they who lived in his Time, might, with V Pounds, purchase so much Bread, so much Drink, Meat, Cloth, Firing, Books, and other Necessaries, or Conveniencies: I know not exactly how much, nor is it material: I only say, the Founder intended I might keep such an Estate, as would suffice to procure the same Bread, Drink, Meat, Cloth, Books, *&c.* as the other might have procured for V Pounds, 260 Years ago. But this I cannot possibly do with VI Pounds, as Things go now, nor it may be, with four times as much. . . . This is a clear Proof, that Regard both may and must be had, to the different Value of Money, at different Times; and that the Founder's visible Intention is better answered by such Regard, than it would be by a strict and obstinate Adherence to the bare Letter of the Statute."

The author goes on to say that it is not his purpose to determine exactly to what extent prices have risen, or the value of the pound has changed: "I leave that to Others, to gather from the particular Accounts of Things that I shall give them, from our Historians." But he was sure that although a pound in the time of Henry the Sixth might be worth 4 or 5, or more, in his own time, it was certainly not worth 20 or 30. This leads to the chapters on the description of gold and silver coins, to serve as the basis of the prices quoted in the succeeding chapters. Chapter IV. "Of the Price of Corn, and other Commodities, for 600 Years Last Past." is introduced as follows:

"Having dispatch'd, with what *exactness* I could, the Chapters of *Moneys*, I am now come to speak to the Price of *Corn* and other *Commodities;* which

is (whether you know it, or not) the readiest way to the solution of your *Third*, and most material Question. For, your Business is to know (as near as you can) what Estate or Summ of Money will *now-a-days* be equal, or equivalent to *five Pounds* (let that be the supposed Summ in this Discourse) in the Reign of King *H.* VI. and to this End, your Care will be, to find out how much *Meat, Drink,* or *Cloth,* might be purchased in *H.* VI. Reign, with V *l.* and then to find out, how much of the Money now current, will be required to purchase the same quantity of *Meat, Drink,* and *Cloth.* For, since Money is of no other use, than as it is the Thing with which we purchase the Necessaries and Conveniencies of Life, 'tis evident, that if V *l.* in *H.* VI. Days, would purchase 5 *Quarter of Wheat,* 4 *Hogsheads of Beer,* and 6 *Yards of Cloth,* he who then had V *l.* in his Pocket, was full as rich a Man as he who has now XX *l.* if with that XX *l.* he can purchase no more *Wheat, Beer,* or *Cloth,* than the other. I do not mean hereby to pre-judge this to be the Proportion; but use this Instance to let you see, that this is the properest way of coming to know, what Estate is *now* most answerable, to an Estate of V *l. per An.* 250 Years ago. . . . "

Curiously enough, this concept of a weighted aggregative index number, as we call it, became transmuted into an average-of-relatives in Chapter VI, the Conclusion, for the price increase of each of several sample commodities is estimated and a mental average taken, to express the author's final judgment. After explaining the difference in the number of shillings in a pound between the two dates under discussion, the Bishop suggests that instead of taking one particular year at the present and 250 years earlier, "you must take the Price of every particular Commodity, for as many Years as you can (20, if you have them) and put them all together; and then find out the common Price; and afterwards take the same Course with the Price of Things, for these last 20 Years; and see what Proportion they will bear to one another; for that Proportion is to be your Rule and Guide." The succeeding paragraph illustrates the method by assuming certain prices for wheat, oats, beans, ale, and cloth ("Good *Cloth,* such as was to serve the best *Doctor* in your *University,* for his Gown"); but from the language it appears that the Bishop believed that he was using realistic prices. Wheat, oats and beans were found to have increased in price by about six-fold over the 200 years. "But you must not expect that every Thing will answer thus exactly." Ale and cloth had risen about five-fold in price, and he had good reason to believe that 200 years earlier beef, mutton, bacon "and other common Provisions of Life, were six times as cheap." The final statement is as follows:

"And therefore I can see no Cause, why 28, or 30 *l. per An.* should now be accounted, a greater Estate, than V *l.* was heretofore, betwixt 1440, and 1460."

Two other applications of the price index concept are mentioned by the author, the first of which can certainly be regarded as important,—in fact a matter of life and death! He quotes Sir *H. Spelman*, "a very competent Judge and Aestimator of these Matters," to the effect that the laws providing capital punishment for conviction for theft of things to the value of twelve pence were being invoked to condemn to death many people whose crime would not have brought the death penalty when the laws were enacted many years earlier. Finally, and to end up on a less gruesome note, the cause of democracy was served by inflation, when the qualification for "*Electors* of Parliament-Men" had been set years before at the possession of lands or tenements to the yearly value of 40 shillings.

> "Whether the Legislative Power, in 1430, did well, and wisely, in reducing the Number of Electors to such as were worth 40 *s. per Annum*, (which cut off many hundred thousand voices, and consequently many occasions of Tumults and Disorders) is not to be doubted over-much; nor yet is to be over-confidently affirmed, because if it had been so wise and useful an Ordinance, it would have still been kept up, in its due Proportion, according to the difference of Times; altho' the Changes of such Moment are not to be frequently and lightly made. But in these Affairs, it is not fit for private People to meddle."

A final bit of advice was given by the Bishop to his correspondent:

> " . . . And that is, That if ever you design to take Orders, and obtain any *Rectory*, *Vicarage*, or higher *Dignity* in the Church, you be, above all Things, careful, how you make any Composition or Agreement, for any long Space of Years, to receive a certain Price of Money, for the Corn that is due to you, altho' for the present it may seem a tempting Bargain, and a profitable Exchange, and rid you of some Trouble, You know not what Time may bring forth, nor what great Alterations may happen, nor what great Mischiefs you, unwittingly, may do your Successors. . . . "

A METHOD OF MAKING ACTUARIAL ESTIMATES FOR A COMPULSORY HEALTH INSURANCE SYSTEM

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THE actuarial basis of a compulsory health insurance system, in the final analysis, resolves itself into a problem of simple arithmetic. Obviously enough money must be raised under the system to pay for the benefits provided thereby, and benefits provided under the plan cannot be more extensive and complete than what can be supported by the health insurance fund. In other words, under a compulsory health insurance plan, as with all other things, it is impossible to get something for nothing, and all that is offered under the insurance system must be paid for out of funds collected from the employer, employee, and/or the government.

There are at least two approaches to the problem of determining the costs of such a sytem. One may fix arbitrarily the maximum amount of contributions that it appears wise or prudent to levy for the plan, thereby determining the amount of money with which services can be bought. Or one may determine what appears to be the minimum number of basic services which should be offered in bringing basic medical care to the desired number of persons, and then, upon a basis of these needed services, determine how much money will be needed to pay a fair price for those services. In either case it will be necessary to estimate as accurately as possible (a) the total or per capita cost of basic services to be afforded, and (b) the total or per capita contribution which will be collected to pay for the services.

Since compulsory health insurance is a new field to the people of this country, both the amount of the levy which can and should be collected for the support of the scheme and the number and nature of what are to be called "basic medical services" afforded to the largest possible number of the population are matters that, for the want of a better method, must be more or less arbitrarily determined. But a start is needed, and enough services under the health insurance system must be offered to meet at least the basic needs of the largest number of persons possible at a cost that will not be over-burdensome for the individual, the employer, or the state or federal government. Otherwise, the plan cannot survive, and cannot be instrumental in meeting the basic difficulties encountered under the system of the private practice of medicine.

Several compulsory health insurance plans were presented at the last session of the California State Legislature. Even though no comprehensive compulsory program has yet been envoked in any state of this country, in view of the widespread application of the health insurance principle in most other advanced nations of the world, and the imminence of its application either upon a state-wide or nation-wide basis in the United States, it seems clear that a sober and sound approach to the actuarial basis of a compulsory plan is already long past due. Inasmuch as an American plan for compulsory health insurance must not only profit from the mistakes that have been made in this form of social insurance abroad, but also must be based upon American experience and American standards, an approach to this problem has little to build upon as a foundation.

In order that a start may be made in the development of a sound actuarial basis for such a program, this discussion will suggest a method of approaching an answer to the question as to how much revenue could be expected to arise under a compulsory health insurance program such as that proposed for California by Governor Warren early in 1945. Several basic computations are involved in the development of a method:

1. Estimates of taxable earnings and tax revenues, by years, during the ten-year period 1938–1947.
2. Estimates of the number of employees and dependents in California who would be brought within the scope of the system outlined in the Governor's proposal (Assembly Bill No. 800), or its counterpart, and introduced in the State Legislature early in 1945.
3. Estimates of the average per capita amounts made available through the health insurance fund and covering, in the main, approximately the same working groups as are now covered under the unemployment compensation law, but including dependent family members as well.

A fourth basic computation, that of estimating the amount of medical benefits that can be offered under the proposed program, cannot be presented within the confines of this paper.

I

Estimates of Taxable Earnings and Tax Revenues in California 1938–1947

Any sound approach to the actuarial basis of a compulsory health insurance system must start with the Federal Census of Population and an analysis of the numbers of persons gainfully employed. The number, sex and age distribution of employees to be covered by the compulsory provisions of a health insurance plan for California have been made as

of January 1, 1935[1] and for 1937,[2] and the method developed need not be re-presented here. It will, of course, be necessary to project population trends for the state from the last Federal Census period (1940) for several years. As indicated below in Table 4, this study projects these trends through the year 1947, at which time it is estimated the state will have a total population of 8,440,000 resident civilians.

The age and sex distribution of the population, and the major occupational groupings of the population are easily obtainable from the

TABLE 1

INCOME PAYMENTS IN CALIFORNIA COMPARED WITH VARIOUS SHARES OF TOTAL INCOME PAYMENTS AND AVERAGE PER CAPITA CIVILIAN INCOME PAYMENTS AFTER FEDERAL TAXES, 1935–1947 (ESTIMATES FROM 1944)

	Total Income Pmts. all persons (M-$)	Income Pmts. to civilians (M-$)	Total Salaries and Wages (M-$)	Total Net Income to Proprietors (M-$)	Dividends, Interest and Net Rent (M-$)	Other Income Pmts. (M-$)	Total Civilian Income Pmts. after Fed. Income Taxes†	Per Cap. Pmts. after Taxes
1935*	$ 3,952	$ 3,952					$ 3,919,000,000	$ 650
1936*	4,786	4,786					4,744,000,000	773
1937*	5,105	5,105					5,029,000,000	779
1938*	4,808	4,808					4,733,000,000	708
1939	5,047	5,047	3,050	750	896	351	4,987,000,000	738
1940	5,605	5,605	3,389	875	954	388	5,546,00,0000	810
1941	7,044	7,000	4,310	1,150	1,190	350	6,910,000,000	987
1942*	9,260	8,960					8,700,000,000	1,189
1943	12,097	11,318	7,810	1,796	1,325	386	10,023,000,000	1,335
1944	—	12,300	8,350	2,000	1,450	500	11,070,000,000	1,405
1945	—	10,500	6,400	3,500		600	9,500,000,000	1,187
1946	—	9,150	5,450	2,900		800	8,250,000,000	989
1947	—	9,400	5,650	2,950		800	8,450,000,000	937

* Detailed estimates not available.

† Allowing for a 10 per cent Federal income tax deduction for the years 1945–1947.

SOURCE: Totals for 1935–1943 inclusive from United States Department of Commerce Reports on Income Payments, by States. Other amounts (years 1944–1947) are estimates based upon projected employment and postwar income studies made by the State Reconstruction and Reemployment Commission, and the Brookings Institution.

Federal Census reports, and require little if any adjustments to provide estimates for the several years in the immediate future for which data must be made available.

Thus the launching point in our study is reached in connection with estimating the amounts of total and per capita income payments, for such data must serve as a basis for estimating the total revenues to be

[1] Dodd, Paul A. and E. F. Penrose, *Economic Aspects of Medical Services, with Special Reference to California*, Graphic Arts Press, (Washington, D.C.) 1939, pp. 445–458.

[2] *Estimating the Costs of Medical Benefits Under a Proposed Compulsory Health Insurance System for California*, by Paul A. Dodd, University of California, April, 1940 (Mimeographed), p. 4.

raised by means of a specified payroll tax schedule as stipulated in the health insurance proposal. These data are presented in Table 1, where phenomenal increases in total income payments received by persons in California between 1935 and 1947 are indicated. In 1935, for instance, persons in California received an estimated total income of $3,952,000,000, or an average per capita income, after federal taxes, of $650. By 1943 this estimated total had increased to over $12,000,000,000, or to an average after federal taxes of $1,335 per capita.

TABLE 2

NUMBER OF EMPLOYEES WHO RECEIVED WAGES IN COVERED EMPLOYMENT (UNEMPLOYMENT INSURANCE ACT) DURING 1940 AND 1943 IN CALIFORNIA

Wage Group	Number and Percentage of Employees			
	1940		1943*	
	Number (in 000s)	Per Cent	Number (in 000s)	Per Cent
$ 1 to 199	579	26.4	928	24.4
200 to 399	254	11.6	400	10.5
400 to 599	189	8.6	280	7.4
600 to 799	149	6.8	213	5.5
800 to 999	152	6.9	176	4.8
1000 to 1499	341	15.5	409	10.8
1500 to 1999	262	12.0	344	9.0
2000 to 2499	144	6.6	291	7.6
2500 to 2999	57	2.7	276	7.3
3000 and over	64	2.9	483	12.7
3000 to 3999†	19	.85	145	3.8
4000 to 4999†	19	.85	145	3.8
5000 and over†	26	1.2	193	5.1
Total	2,191	100.	3,800	100.

* Wages for 1943 represent wages until September 10, 1943.

† Estimated distribution made by the C.E.S.C.

SOURCE: "*A Report of Activities for the Month of January, 1945*," California Employment Stabilization Committee.

The most reliable estimates obtainable indicate that in 1940 total "salaries and wages" in California approximated some $3,389,000,000; by 1943 they had exceeded $7,800,000,000; and in 1944 they had reached a peak of some $8,350,000,000. This latter year the estimated average per capita income payments (after federal taxes) also reached a peak of $1,405. These data also suggest that while the total "wages and salaries" in California had passed their peak with the passing of 1944, still, by 1947 they will probably approach an estimated total of some $5,650,000,000, an amount 65 per cent above the level attained in 1940.

In Table 2 are presented basic data relative to the distribution of earnings among employed workers who received wages in covered employment in California during 1940 and 1943. Since most compulsory health insurance proposals are advanced under the assumption that some minimum earnings level must be applied to establish eligibil-

TABLE 3

TOTAL WAGES, TAXABLE WAGES, AND ESTIMATED TOTAL TAXABLE WAGES UNDER THE WARREN HEALTH INSURANCE PROPOSAL

Estimates Based Upon Employment Covered by the California Unemployment Insurance Act, 1938–1944 (Including Estimates for 1945–1947)

Year	Total Wages† in employment covered by the C.U.I. Act	Taxable Wages subject to the Cal. Unemp. Insurance Act ($3000 limit)	Actual U.C. Tax pmts. 2.7% +1.0% into the Cal. Unemp. Ins. Trust Fund	Est. Size of H. I. Fund on basis of 3.7% ($3000 limit)‡	Est. Total Taxable Wages and Salaries of $4000 or less (Warren)§	Est. Size of H. I. Fund on basis of 3% tax
1938	$2,004,178,555	$2,004,178,555	$ 62,290,744	$ 60,125,000	$1,864,000,000	$ 55,920,000
1939	2,052,137,042	2,052,137,042	77,629,654	61,564,000	1,908,000,000	57,240,000
1940	2,238,118,011	2,025,506,207*	76,615,971	60,765,000	2,082,000,000	62,460,000
1941	2,973,485,949	2,699,093,059*	91,708,084	80,973,000	2,765,000,000	82,950,000
1942	4,280,397,659	3,892,476,135*	118,745,535	116,744,000	3,981,000,000	119,430,000
1943	5,718,447,552	5,098,045,257*	165,109,898	152,941,000	5,318,000,000	159,540,000
1944 (est.)	6,100,000,000	5,400,000,000*	170,347,031	162,000,000	5,673,000,000	170,190,000
1945 (est.)	4,267,000,000	3,840,000,000*	124,800,000	115,200,000	5,968,000,000	119,040,000
1946 (est.)	3,633,000,000	3,270,000,000*	106,275,000	98,100,000	3,379,000,000	101,370,000
1947 (est.)	3,767,000,000	3,390,000,000*	110,175,000	101,700,000	3,503,000,000	105,090,000

* Does not includes wages in excess of $3,000 per year from any single employer.

† Includes all wages in employment covered by the Act without regard to the limit of $3,000 per year per worker for tax purposes.

‡ Actual total contribution rate, because of experience rating, was 3.15 per cent instead of 3.7 per cent (2.7% from employer and 1% from employee).

§ Assumes distribution of earnings in excess of $3,000 per year to be that indicated in Table 2, and Total Taxable Wages during these years to equal (approximately) 60 per cent of Total Salaries and Wages, a proportion which maintained in 1940.

SOURCE: Actual figures compiled by the State of California, Department of Employment, Division of Research and Statistics from E.S.-203 Reports. Estimates made under assumptions that (1) War in Europe will be terminated by July, 1945; (2) War in Orient will be terminated by July, 1946; and (3) Ratios which have prevailed between total Wages and Salaries in Covered Employment and those subject to the California Unemployment Insurance Act during 1940–1944 will, in general, continue through the period 1945–1947.

ity to share in the benefits of the program, these data are important in indicating the number of workers who will qualify under the plan as having earned the minimum amount of wages or more during the year.

The next step in developing actuarial estimates is to determine the amount of taxable wages upon which, under the proposed provisions, a

3 per cent payroll tax would be levied for the health insurance fund. These estimates are presented below in Table 3. Considerable light on the situation, it will be observed, has been shed by the records of the California Employment Stabilization Commission, which since 1938, has been collecting a payroll tax on all taxable wages and salaries in covered industries. By projecting the same relationships which the taxable wages (subject to the California Unemployment Insurance Act) have borne to these total salaries and wages (Table 1) and total wages in covered employment (Table 3), it is possible to estimate the probable revenues flowing into a health insurance fund year by year for the ten-year period 1938–1947. Under the proposed 3 per cent compulsory health insurance payroll tax, a fund of probably more than $100,000,000 a year for the next three years could be anticipated for the purchase of medical care under the program.

II

Estimates of the Number of Employees and Dependents in California Who Would be Brought Within the Scope of the Governor's Proposal

Obviously the number of workers included in any health insurance measure will depend upon the income levels established and the extent and nature of specific exemptions that are made. The most reliable estimates of the number of wage earners throughout the state receiving earnings of varying amounts have been made by the Employment Stabilization Commission, and are set forth above in Table 2. As previously noted, many thousands of wage earners working in covered employment in California make unemployment insurance tax contributions during the course of the year even though their total earnings during the year do not reach $300, the amount stipulated under the Act as being the minimum earnings which qualify a worker to receive benefits under the program.

The figures presented in Table 4 set forth, upon a basis of the records of the California Department of Employment, the actual monthly average of the total number of workers in covered employment coming within the scope of the Unemployment Insurance Act of California, and the estimated number of workers in covered industries with wage credits in excess of $300 (and who are, therefore, eligible for the receipt of unemployment compensation benefits under the California Act) for the years 1938–44 inclusive, and estimates for the years 1945–47.

It is important to note that the estimated number of workers eligible for unemployment compensation benefits, as set forth in Table 4, is approximately 20 per cent higher than the actual monthly average of those who are at work in covered employment. Thus it will be seen, for instance, that in 1940 approximately 1,661,000 workers were eligible

TABLE 4

NUMBER OF RESIDENT CIVILIANS, NUMBER IN LABOR FORCE, NUMBER GAINFULLY EMPLOYED, AVERAGE MONTHLY NUMBER IN COVERED EMPLOYMENT (U. INS. ACT) IN CALIFORNIA
1938–1947

Year	Resident Civilian Population	Estimated % of Gainfully Employed to Total Pop.	Number Gainfully Employed (Civilians)‡	Number in Covered (U. Ins. Act) Employment (Monthly Average)§		Estimated Number Eligible for U.C. Benefits‖
				Number	% of total population	
1938	6,687,000	35	2,341,000	1,280,903	19.2	1,537,000
1939	6,755,000	35	2,364,000	1,269,097	18.8	1,523,000
1940	6,843,000	36	2,482,000	1,384,386	20.2	1,661,000
1941	7,000,000	39	2,730,000	1,672,158	23.9	2,006,000
1942	7,315,000	42	3,072,000	1,981,973	27.1	2,378,000
1943	7,510,000	46	3,464,000	2,274,031	30.3	2,729,000
1944	7,880,000	44	3,448,000	2,202,896	28.0	2,644,000
1945	8,004,000	42	3,362,000	2,001,000	25.0	2,401,000
1946	8,343,000	38	2,170,000	1,919,000	23.0	2,303,000
1947	8,440,000†	35	2,975,000	1,688,000	20.0	2,026,000
	High 9,510,000	35	3,350,000			
1950*	Median 8,650,000	35	3,050,000			
	Low 7,800,000	35	2,750,000			

* Estimates of the California State Reconstruction and Reemployment Commission, presented in *Maximum Estimates of Population Growth in California, 1940–1950* (June, 1944) p. 29.

† Population and Gainfully Employed estimates are based upon the averages of the maximum and minimum estimates made by the SRRC, *Ibid.*, p. 31.

‡ Includes wage and salary workers, employers, own account workers, and unpaid family workers. Figures for 1943 (June) and 1944 (May) are from the SRRC *op. cit.*, Appendix, Table 11.

§ These figures of average monthly employment are not to be confused with the number of persons with wage credits in any year, or the number having wage credits in excess of $300 and so eligible for unemployment benefits. Out of a total of some 3,800,000 persons with some wage credits in 1944, approximately 2,650,000 had wage credits in excess of $300 each, but only 2,204,000 were actually employed in June 1944 in covered employment.

‖ Assuming that at any given time there will be approximately 20% more persons with wage credits in excess of $300 during the current year than are actually employed at the time.

for unemployment compensation benefits in California; in 1942 this number increased to an average of 2,378,000; and in 1943 a peak was reached, at which time some 2,729,000 workers were eligible for benefits under the Unemployment Insurance Act. By 1947 it is estimated that this total number will decrease to slightly more than 2,000,000 workers (2,026,000).

The Governor's bill specifically included as dependents only those who are legally dependent spouses or dependent children under the age of eighteen (Administration Bill #800). It is extremely difficult to arrive at a fair estimate of what these numbers will be per insured worker. Perhaps the simplest and most logical approach to this calculation, at least until more accurate estimates can be made, would be to base the computations upon the ratios that prevailed at the time of the last Federal Census (1940).

TABLE 5

COMPUTATION OF RATIO OF AVERAGE NUMBER OF PERSONS NOT GAINFULLY EMPLOYED TO AVERAGE NUMBER OF PERSONS GAINFULLY EMPLOYED IN CALIFORNIA, 1938–1947

Year	Total Civilian Population (Resident)	Total Gainfully Employed (Covered and Non-covered Employ) (Civilian)	Total No. Not Gainfully Employed	Ratio of No. Not Employed to No. Employed
1938	6,687,000	2,341,000	4,346,000	1.86
1939	6,755,000	2,364,000	4,391,000	1.86
1940	6,843,000	2,482,000	4,361,000	1.76
1941	7,000,000	2,730,000	4,270,000	1.56
1942	7,315,000	3,072,000	4,243,000	1.38
1943	7,510,000	3,464,000	4,046,000	1.17
1944	7,880,000	3,448,000	4,432,000	1.29
1945	8,004,000	3,362,000	4,642,000	1.38
1946	8,343,000	3,170,000	5,173,000	1.63
1947	8,440,000	2,975,000	5,465,000	1.84

These census data show that in 1940 out of a total civilian population of 6,843,000 a total of 2,482,000 persons were gainfully employed in both covered and non-covered employment throughout the State. This meant that there were at that time a total of 4,361,000 who were not gainfully employed. In other words, for every person gainfully employed at that time there was an average of 1.76 persons not gainfully employed. Projecting this relationship analysis through each year of the period (1938–47), we find that the ratio of the persons not gainfully employed to the total number gainfully employed diminished from 1938 steadily down to 1943, and upon a basis of our estimates for the coming years will increase again to the point whereby at 1947 it will have regained its pre-war level of approximately 1 to 1.84.

Another method of estimating the total number of dependents to be included under the Governor's proposal is to examine the relationship between the number of persons gainfully employed (in both covered and non-covered employment) and the total number of families

throughout the State. The ratios reflecting this relationship during the ten-year period under observation are presented in Table 6.

These computations have been made under the assumption that the average number of persons per family within the State (3.2) as revealed by the Federal Census of 1940 will have remained substantially unchanged during the 1938–1947 period.[3] The trends in this ratio from 1938 throughout the ten-year period are significant in the completion of the actuarial estimates herein undertaken. Beginning with a level of 1.12 wage earners per family, on the average, in 1938, the ratio reached

TABLE 6

COMPUTATION OF ESTIMATED AVERAGE NUMBER OF WAGE EARNERS PER FAMILY IN CALIFORNIA
1938–1947

Year	Resident Civilian Population*	Estimated Number Families†	Number Persons Gainfully Employed‡	Estimated Aver. No. Wage Earners Per Family
1938	6,687,000	2,089,688	2,341,000	1.12
1939	6,755,000	2,110,938	2,364,000	1.12
1940	6,843,000	2,138,438	2,482,000	1.16
1941	7,000,000	2,187,500	2,730,000	1.25
1942	7,315,000	2,285,938	3,072,000	1.34
1943	7,510,000	2,346,875	3,464,000	1.48
1944	7,880,000	2,462,500	3,448,000	1.40
1945	8,004,000	2,501,250	3,362,000	1.34
1946	8,343,000	2,607,188	3,170,000	1.22
1947	8,440,000	2,637,500	2,975,000	1.13

* Federal Census to 1940; from that point estimates are made upon a basis of the SRRC forecasts.

† Computed upon basis of 3.2 persons per family in California, which was the average at the time of the 1940 Federal Census. (*Statistical Abstract of the United States*, 1943, p. 48). The average number of persons per family in California at the time of the 1930 Federal Census was 3.34 (*op. cit.*, 1937, p. 48).

‡ Estimates as made in Table 4, except for Census year 1940.

a peak four years later at which time there were throughout the State an estimated 1.48 wage earners per family. The ratio then declines during the remaining years of the period under analysis, until 1947, at which time the average number of wage earners per family probably will have returned to the pre-war ratio of approximately 1.13 (wage earners) to 1 (family).

There appears to be a simple way of making the adjustments which have been made necessary by these far-reaching changes in the conditions of employment. In Table 7 is presented the estimated average number of dependents per employed worker. These computations show the ratio from year to year, based upon the assumption that dependents

[3] This assumption appears justified in the light of the slight change in the average size of California family which, according to the Federal Census, took place between 1930 (3.34) and 1940 (3.2). (See notes under Table 6).

include only the legal spouse and dependent children under the age of 18 years.[4]

TABLE 7

ESTIMATED AVERAGE NUMBER OF DEPENDENTS (LEGALLY DEPENDENT SPOUSE AND DEPENDENT CHILDREN) PER GAINFULLY EMPLOYED WORKER IN CALIFORNIA, 1938–1947

Year	Total Population (Resident Civilian)	Total Gainfully Employed	Aver. No. of Dependents per Employed Worker (Dep. spouse and dep. children under 18) (AB #800)
1938	6,687,000	2,341,000	1.31
1939	6,755,000	2,364,000	1.31
1940	6,843,000	2,482,000	1.24
1941	7,000,000	2,730,000	1.10
1942	7,315,000	3,072,000	.97
1943	7,510,000	3,464,000	.82
1944	7,880,000	3,448,000	.91
1945	8,004,000	3,362,000	.97
1946	8,343,000	3,170,000	1.15
1947	8,440,000	2,975,000	1.30

The 1940 Federal Census showed that out of the total resident civilian population of 6,843,000 persons in 1940, 2,482,000 were gainfully employed. Another 3,065,871 were reported as married dependents not gainfully employed and dependent children (not gainfully employed) under 18 years of age. In other words, at the time of the last Federal Census, there existed an average of 1.24 dependents (as defined in line with the provisions of Governor Warren's Bill) for each gainfully employed worker in California.

It should be noted also that the year to year ratios have been corrected for the increases brought on by wartime employment opportunities which have had the effect of (a) increasing the proportion of those gainfully employed, and (b) reducing the proportion of the number of dependents. Both of these influences have had a considerable effect upon the amount of tax contributions into the proposed health insurance fund, and the average amount per person available for medical benefits.[5]

[4] As provided for in Administration Bill #800.

[5] The year to year variations in this set of ratios have been computed by taking the ratios of dependents per employed worker determined by the 1940 Federal Census (when the relationship between the total number not employed to the total number employed was 176 to 100) as 100 per cent (base year), and then adjusting each year to a corresponding relative ratio. Thus the link relatives become 1938–106, 1939–106, 1940–100, 1941–89, 1942–78, 1943–66, 1944–73, 1945–78, 1946–93, and 1947–105. Thus the ratio of dependents per worker in 1940 (1.24) becomes the base, and the adjusted ratios for 1938 are 106 per cent of 1.24, etc. This adjustment has the effect of correcting for the unusually high employment levels during the peak war years of 1942–45 and therefore results in conservative rather than inflated estimates relating to the size (per capita) of the health insurance fund.

III

Estimates of the Average Per Capita Amounts Made Available for Medical Benefits Through the Health Insurance Fund

It now becomes possible to draw the various sets of estimates together in determining the approximate *per capita* amounts which such a plan would have available for covering the cost of extending medical benefits under the proposal. This brings the actuarial analysis to the crux of the compulsory health insurance proposals, for unless adequate funds are available, medical services cannot be offered to beneficiaries, and the system is faced with financial disaster.

TABLE 8

COMPUTATION OF ESTIMATED AVERAGE NUMBER OF PERSONS (WORKERS AND DEPENDENTS) ELIGIBLE FOR MEDICAL BENEFITS UNDER COMPULSORY HEALTH INSURANCE PROPOSAL* IN CALIFORNIA, TOGETHER WITH ESTIMATED PER CAPITA AMOUNTS AVAILABLE FOR EXPENDITURE FOR MEDICAL BENEFITS
1938–1947

Estimates Limited to Those Earning $4000 and less per year in Covered Employment				Estimated Total Tax Contributions (3% rate)	Aver. Per Capita amt. Available for Med. Benefits
Year	Workers	Dependents	Total		
1938	1,537,000	2,013,000	3,550,000	$ 55,920,000	$15.75
1939	1,523,000	1,995,000	3,518,000	57,240,000	16.27
1940	1,661,000	2,060,000	3,721,000	62,460,000	16.79
1941	2,006,000	2,207,000	4,213,000	82,950,000	19.69
1942	2,378,000	2,307,000	4,685,000	119,430,000	25.49
1943	2,729,000	2,238,000	4,967,000	159,540,000	32.12
1944	2,644,000	2,406,000	5,050,000	170,190,000	33.70
1945	2,401,000	2,329,000	4,730,000	119,040,000	25.17
1946	2,303,000	2,648,000	4,951,000	101,370,000	20.47
1947	2,026,000	2,634,000	4,660,000	105,090,000	22.55
Ten-year aver.			4,405,000	$103,323,000	$23.46

* Assuming same industry group coverage as those groups of workers presently covered by the State Unemployment Insurance Act. Excluded therefore are Federal and State employees, and certain other groups which might be included under the Governor's proposals.

Comparisons of the estimated total number of insured persons, together with the total tax contributions in covered industries under a compulsory system, and per capita averages, year by year, throughout the ten-year period are set forth in Table 8. As must be expected in view of constant fluctuations in employment and earnings, these data indicate a marked variation from year to year in the estimated total tax contributions accruing to the Health Insurance Fund. In the face of inevitable changes in the estimated total numbers of beneficiaries,

these changes mean variations in the average amount per beneficiary available for the purchase of health services. The estimated per capita amount, for instance, which would be available under the general provisions of A.B. #800 increases from $15.75 in 1938 to $16.79 in 1940, $25.49 in 1942, and $33.70 in 1944; it then declines to $22.55 in 1947.

In a critical analysis of these basic estimates it is important to examine the averages that may be expected to maintain throughout the entire ten-year period. Especially does this appear to be advisable, since wartime conditions have already brought, and promise to continue to bring, basic changes in the economy of the State. Averages over the full period 1938–1947 tend to minimize both the highs and the lows of individual years within the period, and present steadier estimates over a longer period of time. Hence such averages might be expected to indicate with reasonable conservatism the conditions in general to be experienced during the starting years of a compulsory health insurance plan.

These ten-year averages, set forth in Table 8 above, suggest with reasonable certainty that amounts in the health insurance fund will average, year in and out for the coming few years, substantially more than $20 per annum per insured person. In fact the yearly estimates (demonstrated previously to have been made conservatively) during 1945, 1946 and 1947, fall as low as $20.47 during one year only, and average over the ten-year period more than $23.00 per capita per year.

These data indicate strongly that for the immediate years ahead there should be available within the Health Insurance Fund under the Governor's proposal some $20–$22 per beneficiary (both worker and dependent) for the extension of medical benefits as provided under the plan, and exclusive of administrative costs.

APPROXIMATION OF CHI-SQUARE BY "PROBITS" AND BY "LOGITS"

JOSEPH BERKSON, M.D.
Division of Biometry and Medical Statistics, Mayo Clinic, Rochester, Minnesota

IF A function $\hat{Q}$ is fitted to a series of observed rates q, the value of chi-square for the ith rate q_i based on n_i individuals is

$$\chi^2 = \frac{(X - m)^2}{m} = n_i \frac{1}{\hat{P}_i \hat{Q}_i} (q_i - \hat{Q}_i)^2. \tag{1}$$

In the method employed by Bliss,[1] and Bliss and R. A. Fisher[2] for fitting the integral of the normal curve with the use of a linear transformation as "probits," there is implicit an approximation

$$q - \hat{Q} \rightleftarrows \hat{Z}(p_r - \hat{P}_r) \tag{2}$$

in which p_r and $\hat{P}_r$ are the probits corresponding to q and $\hat{Q}$ respectively, the probit being 5 plus x in the normal integral

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-x^2/2} dx = \text{rate}$$

$\hat{Z}$ is the ordinate of the normal curve at x for the fitted rate $\hat{Q}$ and $\hat{P} = 1 - \hat{Q}$. If the approximation (2) for $(q - \hat{Q})$ is substituted in (1), we have as an approximation of chi-square

$$\chi^2 \rightleftarrows n_i \frac{\hat{Z}_i^2}{\hat{P}_i \hat{Q}_i} (p_r - \hat{P}_r)^2. \tag{3}$$

In the method of Bliss and Fisher, the quantity on the right of (3) summed for all the observations, is minimized. This is accomplished by obtaining a least squares solution for $\hat{P}_r$ which is a straight-line function of the log dose, the weights for the solution being

$$n_i \frac{\hat{Z}_i^2}{\hat{P}_i \hat{Q}_i}.$$

The logistic may be fitted with the use of logits by a method precisely analogous to that used for probits. The approximation corresponding to (2) would then be

$$q - \hat{Q} \rightleftarrows - \hat{P}\hat{Q}(l - \hat{L}) \tag{4}$$

TABLE 1

COMPARISON OF LOGIT AND PROBIT APPROXIMATIONS TO x^2 WITH ACTUAL VALUE OF x^2

q	Q	$\frac{1}{\text{logit } q}$	L logit Q	P_r probit q	P_r probit Q	$\frac{Z^2}{PQ}$	x^2			Ratio to actual x^2	
							Actual $\frac{1}{PQ}(q-Q)^2$	Logit $pq(l-L)^2$	Probit $\frac{Z^2}{PQ}(p_r-P_r)^2$	Logit	Probit
.1	.105	2.197223	2.142862	3.718448	3.746435	.351840	.000266	.000266	.000275	1.00	1.03
.105	.1	2.142862	2.197223	3.746435	3.718448	.342218	.000278	.000278	.000268	1.00	0.96
.1	.2	2.197223	1.386294	3.718448	4.158379	.489866	.062500	.059185	.094808	0.95	1.52
.2	.1	1.386294	2.197223	4.158379	3.718448	.342218	.111111	.105217	.066233	0.95	0.60
.4	.5	0.405464	0.000000	4.746653	5.000000	.636620	.040000	.039456	.040861	0.99	1.02
.5	.4	0.000000	0.405464	5.000000	4.746653	.621919	.041667	.041100	.039918	0.99	0.96

in which l and $\hat{L}$ are the observed and fitted logits respectively, the logit being

$$l = \ln \frac{p}{q} \qquad \hat{L} = \ln \frac{\hat{P}}{\hat{Q}}.$$

If the approximation (4) for $(q-\hat{Q})$ is substituted in (1), we have as the approximation for chi-square

$$\chi^2 \rightleftharpoons n_i \hat{P}_i \hat{Q}_i (l_i - \hat{L}_i)^2. \tag{5}$$

The quantity on the right of (5) summed for all the observations is then to be minimized. This is accomplished by obtaining a least squares solution for $\hat{L}$ which is a straight line function of the log dose, the weights for the solution being $n_i \hat{P}_i \hat{Q}_i$.

In (5) there is a simplification as compared with (3) because $\hat{Z}$, which is the first derivative of the function with respect to the linear transformation and for the probit is equal to the normal ordinate, is for the logistic equal to $\hat{P}\hat{Q}$, and so cancels out that value in the denominator of (1).

If "corrected" logits are to be used analogous to those used for probits, a similar simplification is effected. The "corrected" probit is a value p'_r substituted for the observed p_r, such as to fulfill (2) exactly instead of approximately. For the probit this gives

$$p_r' = \hat{P}_r + \frac{(q - \hat{Q})}{\hat{Z}}. \tag{6}$$

If analogously we evaluate a "corrected" logit l' to substitute for the observed l in order to make (4) hold exactly, we have for the "corrected" logit

$$l' = \hat{L} - \frac{(q - \hat{Q})}{\hat{P}\hat{Q}}. \tag{7}$$

In the method advanced by me in a former article for the logistic,[3] a different approximation than (4) is utilized

$$q - \hat{Q} \rightleftharpoons - \sqrt{pq\hat{P}\hat{Q}}\,(l - \hat{L}). \tag{8}$$

Substituting approximation (8) in (1) gives as the approximation for chi-square the sum of which is to be minimized

$$\chi^2 \rightleftharpoons n_i p_i q_i (l_i - \hat{L}_i)^2. \tag{9}$$

In the use of (3) for probits or (5) for logits, a preliminary fit has to be made to obtain values of $\hat{P}\hat{Q}$ which are required for the weights used

in the solution. If (9) is used, no preliminary fit is needed since the weights are in terms of the observed rates pq. The use of (9) therefore considerably simplifies the solution.

It is however pertinent to determine the relative precision of the approximation of chi-square (3) utilized in the probit method and (9)

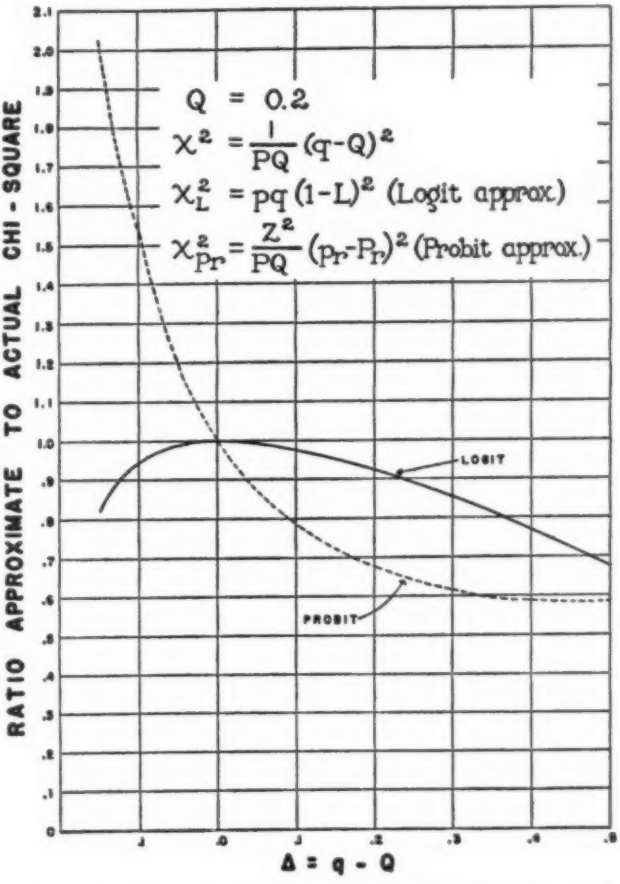

FIG. 1. RATIOS OF THE LOGIT AND THE PROBIT APPROXIMATIONS TO THE EXACT VALUES OF CHI-SQUARE FOR Q=0.2 AND VARIOUS VALUES OF $q-Q$.

used in the logit method. This has been attempted by taking some specific hypothetical examples and arithmetically evaluating the comparison. In Table 1 is shown for a range of q and Q, where q is considered the observed and Q the corresponding "true" rate, a comparison of each approximation with the actual chi-square. In Figure 1 is shown

the locus of the ratio of the approximate to the actual chi-square for the value $Q=0.2$, and various differences $(q-Q)$.

The following appears to be generally true: (*a*) The approximation of both probits and logits approaches the correct value of chi-square as the difference $(q-Q)$ approaches zero or as q or Q approaches 0.5 or as both conditions are met; (*b*) the approximation of logits given by (9) is closer than the approximation of probits given by (3); (*c*) the logit approximation gives always a smaller value than the actual, the probit sometimes lower, sometimes higher; (*d*) the variability of the difference from actual is greater for the probit than for the logit.

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[1] Bliss, C. I.: The determination of the dosage-mortality curve from small numbers. *Quart. Jour. Pharm. & Pharmacol.* **11**: 192–216, 1938.

[2] Bliss, C. I. (with an appendix by Fisher, R. A.): The calculation of the dosage mortality curve. *Ann. Applied Biol.* **22**: 134–167, 1935.

[3] Berkson, Joseph: Application of the logistic function to bio-assay. *Jour. Am. Stat. Assoc.* **39**: 357–365 (Sept.) 1944.

SEDLEY ANTHONY CUDMORE 1878–1945

THE DEATH of Dr. S. A. Cudmore, head of the Dominion Bureau of Statistics in Canada on October 17th while attending the United Nations Food and Agricultural Conference in Quebec City brought to a close the career of a distinguished Canadian public servant. His mastery of a wide range of economic, statistical and historical knowledge enabled him to carry out the responsibilities of Dominion Statistician with great success. He came to the Bureau shortly after its formation in 1918 and contributed much to its rapid development in the various positions he held since that time.

He was born in County Cork, Ireland, on November 27th 1878, and was a son of the late Thomas Gardiner Cudmore and his wife Caroline Ellen Sedley. His maternal grandfather was Lieutenant Colonel Anthony G. Sedley, a veteran of the Peninsular Wars and Waterloo and Governor of the Military Knights of Windsor.

Emigrating to Canada when he was nine he lived in Brampton, Ontario, where he obtained his public and secondary education. His insatiable thirst for education had to be satisfied the hard way, his high school career having been interrupted by pecuniary difficulties which led him to become a printers' apprentice at the age of thirteen. After resuming his studies he matriculated and won the Prince of Wales Scholarship for general proficiency.

In 1899 he entered the University of Toronto utilizing his training as a compositor during vacations and for shorter periods to earn the funds necessary to defray his expenses. In 1905 he graduated with high honours having won a gold medal in classics and the Flavelle Travelling Scholarship. At Wadham College, Oxford, he studied history and economics, taking his B.A. degree and later his M.A. at that University.

Inclined towards journalism he did some work for London papers and was, for a time, a sub-editor on the *London Standard*. In 1908 he returned to Canada to become instructor in Political Economy at the University of Toronto. By 1917 he had become assistant-professor.

In 1919 he gave up teaching to take the post of Chief of Education Statistics in the recently created Dominion Bureau of Statistics. From 1920–1935 he was chief of General Statistics and Editor of the Canada Year Book. Under his leadership the latter steadily gained in comprehensiveness and quality until it ranked among the best in the world.

The good reputation which the Bureau of Statistics had won in other countries led to an invitation from Palestine for someone to assist them in the organization of their statistics. Dr. Cudmore was loaned for this purpose in 1935. He remained there as Government Statistician until

1938 and organized their Bureau of Statistics. Returning to Canada in 1939 he was appointed Assistant Dominion Statistician and in 1942, on the retirement of Dr. R. H. Coats, he became Dominion Statistician.

Less than a year ago his Alma Mater recognizing his distinguished services, conferred on him the honorary degree of Doctor of Laws.

He was the author of two books: *A History of the World's Commerce* and *Applied Economics* and contributed many articles to economic journals and other publications.

His extensive statistical and economic knowledge led to his attendance as economic adviser to the Canadian Government delegation at the Imperial Conference in London in 1926. He was a member of the American Statistical Association, and served as Assistant Treasurer for Canada from 1941 until his death. He was a fellow of the Royal Economic Society, the Royal Statistical Society and the Royal Society of Canada; one of the three Canadian members of the International Institute of Statistics and a member of the Inter American Statistical Institute. He had accepted the position of Secretary and Vice-President of the Canadian Political Science Association and President of the Professional Institute of the Civil Service of Canada.

In 1910 he married Phoebe Amelia Magee. His son James served with the Royal Canadian Artillery in Europe.

HERBERT MARSHALL

PROCEEDINGS

105TH ANNUAL MEETING

STATLER HOTEL, CLEVELAND, OHIO

PROGRAM

Thursday, January 24, 1946

—9:30 A.M.—

FACTORS DETERMINING INCOME AND EMPLOYMENT
(With Econometric Society)

Chairman: Arthur Smithies, Bureau of the Budget

A Macro-Economic System, U. S. A., 1920–1941
Lawrence R. Klein, Fellow of the Social Science Research Council

Interrelationships of Income, Prices, Demand and Production at Full Employment
W. D. Evans, Jerome Cornfield, Marvin Hoffenberg, Bureau of Labor Statistics

—2:30 P.M.—

FACTORS DETERMINING INCOME AND EMPLOYMENT (*continued*)
(With Econometric Society)

Chairman: O. C. Stine, Bureau of Agricultural Economics

Some Factors Governing the Length of Inventory Cycles
Lloyd R. Metzler, Board of Governors of the Federal Reserve System

The Relationship between the Rate of Savings and National Income
Wladimir Woytinsky, Social Security Board

Capital Expansion and Full Employment
Evsey D. Domar, Board of Governors of the Federal Reserve System

LABOR FORCE MEASUREMENT AND NATIONAL EMPLOYMENT POLICY

Chairman: Howard B. Myers, Committee for Economic Development

Objectives, Uses and Types of Labor Force Data in Relation to Economic Policy
Louis J. Ducoff and Margaret Jarman Hagood, Bureau of Agricultural Economics

Recent Experience with Problems of Measurement
Gertrude Bancroft and Emmett H. Welch, Bureau of the Census

Employment Statistics in the Planning of a Full Employment Program
Charles Stewart, Bureau of Labor Statistics, and Loring Wood, Bureau of the Budget

NUMERICAL SOLUTION OF REGRESSION EQUATIONS

(With Institute of Mathematical Statistics)

Chairman: W. Edwards Deming, Bureau of the Budget

A Machine for the Determination of Correlation and Regression Coefficients
Guy Orcutt, Massachusetts Institute of Technology

A Square Root Method for the Solution of Regression Equations
D. B. Duncan, Royal Australian Air Force

Error Control in Matrix Calculation
F. E. Satterthwaite, Aetna Life Insurance Company

The Compact Computation of Canonical Correlations
P. S. Dwyer, University of Michigan

Friday, January 25, 1946

—9:30 A.M.—

CONSUMER EXPENDITURES AND SAVINGS

Chairman: Morris A. Copeland, National Bureau of Economic Research

Measuring and Forecasting Consumption
Frank Garfield, Board of Governors of the Federal Reserve System

Estimating Post War Savings
George Katona, Bureau of Agricultural Economics

Determinants of National Purchasing Power
Everett E. Hagen, Office of War Mobilization and Reconversion

Discussion: Margaret G. Reid, Bureau of Human Nutrition and Home Economics
Margaret Scattergood, American Federation of Labor

USES OF STATISTICAL ANALYSIS IN WAGE-PRICE POLICY

Chairman: Winfield Riefler, Institute for Advanced Study

Uses of Statistical Analyses in National Wage-Price Policy
Harry Magdoff, Department of Commerce

Uses of Statistical Analyses in Industry Wage-Price Policy (Illustration: automobile and steel)
Harold H. Wein, Department of Justice

Uses of Statistical Analyses by Labor in Wage-Price Policy (Illustration: General Motors)
Louis H. Bean, Bureau of the Budget

BIOLOGICAL ASSAY

(Biometrics Section of the ASA)

Chairman: E. J. deBeer, Wellcome Research Laboratory

Experimental Design for Slope-Ratio Assays
C. I. Bliss, Connecticut Agricultural Experiment Station

Statistical Aspects of the Measurement of Virus Activity
W. C. Price, University of Pittsburgh

Clinical Tests on Comparative Effectiveness of Analgesic Drugs
E. M. Jellinek, Yale University

An Analysis of Collaborative Chick Assays for Vitamin D
Paul Homeyer, Iowa State College

ESTIMATING RELATIONS FROM NONEXPERIMENTAL OBSERVATIONS
(With Econometric Society and Institute of Mathematical Statistics)

Chairman: Mordecai Ezekiel, Department of Agriculture

The Economist's Problem of Statistical Inference
Jacob Marschak, Cowles Commission
Prediction and Structural Estimation
Leonid Hurwicz, Cowles Commission

—12:00 M.—

LUNCHEON—CONFERENCE ON CENSUS TRACTS

Chairman: Howard Whipple Green, American Statistical Association Census Tract Committee

Some Problems Incident to the 1950 Census Tract Program
Howard G. Brunsman, Bureau of the Census
Problems of Tracting Metropolitan Districts
C. E. Batschelet, Bureau of the Census
Summary of the Questionnaires from 60 Key Persons
Esther M. Wright, Bureau of the Census
How Census Tracts Have Been Put to Work in Cleveland (Illustrated)
Howard Whipple Green, Secretary, Cleveland Health Council and Director, Real Property Inventory of Metropolitan Cleveland
Discussion: Census Tract Key Persons and Others

LUNCHEON—BIOMETRICS SECTION BUSINESS MEETING

Chairman: C. I. Bliss, Chairman of the Biometrics Section of the American Statistical Association

—2:30 P.M.—

MEASUREMENT OF PRODUCTIVITY IN THE UNITED STATES

Chairman: Everett Hagen, Board of Governors of the Federal Reserve System

W. D. Evans, Bureau of Labor Statistics
Charles E. Young, Westinghouse Corporation
Discussion: Martin R. Gainsbrugh, National Industrial Conference Board

ESTIMATING RELATIONS FROM NONEXPERIMENTAL OBSERVATIONS (*continued*)
(With Econometric Society and Institute of Mathematical Statistics)

Chairman: R. L. Anderson, North Carolina State College
Iterative Computation Methods in Estimating Simultaneous Relations
Tjalling Koopmans and Roy B. Leipnik, Cowles Commission
Multivariate Analysis in Economics
Gerhard Tintner, Iowa State College

EXPERIMENTAL DESIGNS AND THEIR ANALYSIS

(Biometrics Section of the ASA with the Institute of Mathematical Statistics)

Chairman: Gertrude M. Cox, North Carolina State College

On the Use of Orthogonal Functions in the Analysis of Incomplete Latin Squares
D. B. DeLury, Virginia Polytechnic Institute

Use of Adjusting Factors in the Analysis of Data with Disproportionate Subclass Numbers
R. E. Patterson, Texas A. & M. College

Selection of Sample Size for Detecting Treatment Differences
A. M. Mood, Iowa State College

Rectangular Lattices
Boyd Harshbarger, Virginia Agricultural Experiment Station

Saturday, January 26, 1946

—9:30 A.M.—

AN APPRAISAL OF INDUSTRY AND BUSINESS STATISTICS

Chairman: Winfield Riefler, Institute for Advanced Study

Introductory Statement:
Willard L. Thorp, Department of State

Chemical Statistics
C. W. Bell, Hercules Powder Company

Market Analysis Statistics
D. R. G. Cowan, Cleveland

Retailing Statistics
E. V. Gault, University of Michigan

Electrical Goods Statistics
Stanley Holme, General Electric Company

Development of an International Statistical Program for Pulp Producers
Oliver M. Porter, U. S. Pulp Producers' Association

Food Statistics
F. E. Ridder, General Foods Corporation

General Summary:
John W. Love, Scripps-Howard Newspapers

SAMPLING IN THE SOCIAL SCIENCES

(With Econometric Society and Institute of Mathematical Statistics)

Chairman: W. Edwards Deming, Bureau of the Budget

Problems and Methods of a Sample Survey of Business
M. H. Hansen, Bureau of the Census

Problems of Area Sampling in Agriculture
J. R. Goodman, Bureau of the Census; and
E. E. Houseman, Bureau of Agricultural Economics

Problems of Area Sampling in Population Surveys
B. J. Tepping and J. Steinberg, Bureau of the Census

STATISTICAL PROBLEMS OF PERSONNEL MANAGEMENT

Chairman: Dwight A. Stewart, Radio Corporation of America

Statistical Needs in Personnel Administration
W. D. Evans, Bureau of Labor Statistics
Statistical Problems of Job Evaluation
Franklin G. Moore, Western Reserve University
Statistical Problems in Worker Evaluation
D. J. Bolanovich, Radio Corporation of America
Prepared Discussion: C. H. Lawshe, Purdue University

—12:30 P.M.—

LUNCHEON—STATISTICAL NEEDS FOR ECONOMIC POLICY FORMATION

Chairman: Leonard P. Ayres, Cleveland Trust Company
Theodore O. Yntema, Committee for Economic Development

Prepared Discussions: Andrew Court, General Motors Corporation
A. Loveday, Princeton University
A. Smithies, Bureau of the Budget
K. Williams, Board of Governors of the Federal Reserve System

—2:30 P.M.—

SAMPLING IN THE SOCIAL SCIENCES (*continued*)

(With Econometric Society and Institute of Mathematical Statistics)

Chairman: Samuel S. Wilks, Princeton University

The Problem of Non-response
W. N. Hurwitz, Bureau of the Census
Relative Accuracies of Systematic and Stratified Random Sampling for a Specified Class of Populations
W. G. Cochran, Iowa State College
*On the Design of a Sample of Dealers' Inventories**
W. Edwards Deming, Bureau of the Budget; and
Willard Simmons, Office of Price Administration

HOW CAN INDUSTRY AND BUSINESS STATISTICS BE EFFICIENTLY COLLECTED?

Chairman: Winfield Riefler, Institute for Advanced Study

(A panel discussion by the speakers from the two sessions "An Appraisal of Industry and Business Statistics" and "Statistical Needs for Economic Policy Formation.")

—3:30 P.M.—

THE U. S. GOVERNMENT PROGRAM FOR STATISTICS

Chairman: William R. Leonard, Bureau of the Budget

Earl Constantine, National Association of Hosiery Manufacturers

* See page 16 of this issue.

William H. England, Federal Trade Commission
Philip M. Hauser, Department of Commerce
A. Ford Hinrichs, Bureau of Labor Statistics
George A. Lamb, Department of the Interior
Conrad Taeuber, Department of Agriculture

—6:00 P.M.—

ANNUAL DINNER—THE PRESIDENTIAL ADDRESS

Toastmaster: E. Grosvenor Plowman, United States Steel Corp.
The Advancing Statistical Front
President Walter A. Shewhart, Bell Telephone Laboratories

ANNUAL BUSINESS MEETING

Election of Officers
Committee Reports
Announcement of Fellows for 1945
Consideration of Revision of Constitution
Willard L. Thorp, Department of State, Chairman of ASA Committee on Structure

Sunday, January 27, 1946

—9:30 A.M.—

ACCEPTANCE SAMPLING BY ATTRIBUTES
(With Institute of Mathematical Statistics)

Chairman: J. W. Tukey, Princeton University
Prewar Developments
Paul Peach, North Carolina State College
Wartime Developments
Edwin G. Olds, Carnegie Institute of Technology
Discussion: W. Bartky, University of Chicago
H. R. Bellinson, Army Ordnance Department
D. H. Schwartz, Quartermaster Corps

—2:30 P.M.—

ACCEPTANCE SAMPLING BY VARIABLES
(With Institute of Mathematical Statistics)

Chairman: J. W. Tukey, Princeton University
Lot Quality Measured by Average or Variability
J. H. Curtiss, Bureau of Ships
Lot Quality Measured by Proportion Defective
Allen Wallis, Columbia University
Discussions: K. J. Arnold, University of Wisconsin
A. M. Mood, Iowa State College
E. M. Schrock, Army Ordnance
A. E. R. Westman, Ontario Research Foundation

MINUTES OF THE ANNUAL BUSINESS MEETING

The American Statistical Association convened for its 105th Annual Business Meeting at 6:30 P.M., Saturday, January 26, 1946, in the Ball Room of the Hotel Hollenden in Cleveland, Ohio. E. Grosvenor Plowman presided as Toastmaster and there were 140 members and several guests in attendance.

Immediately after the dinner, Theodore H. Brown, Chairman of the Committee on Fellows, read the following report for his Committee:

The Committee on Fellows takes pleasure in reporting the election of 12 members of the Association as Fellows. We have the honor of announcing the election of

Edith Abbott

Professor and dean emeritus of the Graduate School of Social Service Administration of the University of Chicago. A graduate of the University of Nebraska and the University of Chicago; research worker, teacher and administrator; a pioneer in the statistical study of social problems, and in the teaching of methods for studies in social statistics.

A. Ford Hinrichs

Acting Commissioner of Labor Statistics. Graduate of Cornell and Columbia Universities; past vice-president of the Association; teacher, author, director of a Bureau of Business Research, and now administrator of the Bureau of Labor Statistics providing the public with many basic statistical data.

Lester S. Kellogg

Chief of the Prices and Cost of Living Branch, Bureau of Labor Statistics. Graduate of Northwestern University and the University of Chicago; Secretary of the Association; former teacher of statistics; member of the statistical staff of the War Production Board; now administrator of an important government statistical agency in which his work has advanced techniques in collection and compilation of index numbers of prices; enthusiastic worker in advancing the aims of our Association.

William R. Leonard

Deputy Chief of the Division of the Statistical Standards of the Bureau of the Budget in Washington. Graduate of Whitman College, Tufts, and Cornell; teacher of statistics and economics; tireless and effective worker in the coordination and development of the Federal statistical program since the organization of the Central Statistical Board in 1934.

Edward C. Molina

Retired from the Bell Laboratories. A scholar recognized by mathematicians as one of the leading authorities on the theory of probability. The

legion users of dial telephones are indebted to his mastery of the theory of probability and the practical use of statistics for prompt connections at minimum cost whenever they use dial phones.

Hugo Muench

Rockefeller Foundation. Graduate of Cornell, Washington, and Johns Hopkins Universities; doctor of medicine and public health. He has used statistics extensively in connection with international health problems such as the control of yellow fever.

E. Grosvenor Plowman

Vice President United States Steel Corporation. Graduate of Dartmouth, Harvard, Denver and the University of Chicago; at present a director of the Association; formerly a teacher and now a business administrator; leader in the use of statistics to make business function more effectively.

Leslie E. Simon

Colonel United States Army, Director of the Ballistic Research Laboratory of the Aberdeen Proving Ground. Graduate of West Point. Recognizing early the importance of quality control in the manufacture of munitions for an industrial war, he has been a pioneer in this area of the application of statistics.

Mary Van Kleeck

Russell Sage Foundation, New York City. Graduate of Smith College; former vice president of the Association; and for many years Chairman of its Committee on Employment Statistics; internationally known for her researches in social problems in which the use of statistics has played an important part.

Abraham Wald

Professor of Mathematical Statistics, Columbia University. Graduate of the University of Vienna. A research worker who has made important contributions to the development of pure mathematics as well as economic statistics and especially to the mathematical theory of statistics.

Frederick V. Waugh

Office of the Director of War Mobilization and Reconversion in Washington. Graduate of Massachusetts Agricultural College, Rutgers, and Columbia; teacher and specialist in agricultural economics and statistics. Chief of the Marketing Research Division of the Bureau of Agricultural Economics and staff member of the War Food Administration. He has used statistics and statistical methods extensively in the administration of agricultural programs.

Abel Wolman

Sanitary engineer. A graduate of Johns Hopkins University; teacher and

consultant; internationally known as an authority on engineering who has made dry statistics fluid in the solution of problems on water supply without which, regardless of the belief of some, cities cannot survive.

THEODORE H. BROWN, *Chairman*
LOWELL J. REED
JOSEPH S. DAVIS
ARYNESS J. WICKENS
HAROLD HOTELLING

Walter A. Shewhart, President of the Association for 1945, delivered his Presidential Address,[1] *The Advancing Statistical Front*, after which the meeting proceeded to the business of the evening, with Dr. Shewhart presiding.*

The Secretary, Lester S. Kellogg, gave the Annual Report of the Board of Directors.[2]

Aryness Joy Wickens, author of the amendment to Article III of the Constitution, which was passed at the 104th Annual Meeting, rose to withdraw her amendment which provided that "The number of Fellows shall not exceed three hundred at any time." Mrs. Wickens stated that after a year's work with the Committee on Fellows, she felt the amendment to be undesirable. Chester I. Bliss, who had seconded her amendment, agreed to its withdrawal. However, since the amendment had been approved at the previous meeting, the By-Laws required that it be put to a vote. A vote was taken and the amendment was defeated.

The amendment to Article XII of the Constitution, which was passed at the 104th Annual Meeting, was presented to the membership for its approval and was passed unanimously.

Article XII—Amendments

The Constitution may be amended either at an Annual Meeting of the Association or by mail ballot. A proposed amendment must be submitted by at least ten members of the Association in writing to the Board of Directors which in turn shall submit it with its recommendation to the members of the Association not less than 60 days prior to the Annual Meeting at which it is to be voted upon or not less than 60 days prior to the date upon which the mail ballot is to be taken. The adoption of a proposed amendment shall require the affirmative vote of two-thirds of the members present and voting at the Annual Meeting at which it is voted upon, or if the amendment is voted upon by mail ballot, of two-thirds of the members whose mail ballots are returned within 30 days after the date of original mailing.

The Secretary recommended that By-Law number 2 which provides that "Regular Members and Fellows shall pay annual dues of $5.00 payable at the beginning of the calendar year, . . . " be changed to read: "Regular Members and Fellows shall pay annual dues of $5.00, $3.00 of which is

* The Board of Directors having received no correction to the minutes of the 104th Annual Business Meeting, they were considered approved as printed in the March 1945 JOURNAL.

[1] Printed on page one of this issue.

[2] Printed on page 88 of this issue.

for one year's subscription to the *Journal of the American Statistical Association* and 50 cents for one year's subscription to the *American Statistical Association Bulletin*, payable at the beginning of the calendar year, . . ." The amendment was passed.

W. G. Cochran reported for the Resolutions Committee (W. G. Cochran and E. Grosvenor Plowman) and proposed the following resolutions:

1. Whereas, the National Bureau of Economic Research has completed its first quarter century of service to the Nation, and

Whereas, under the leadership of Dr. Wesley C. Mitchell, this Bureau has made an outstanding contribution in its numerous research projects and activities,

Therefore, be it resolved, that the American Statistical Association, in annual meeting assembled, hereby approves this richly deserved resolution of congratulation for work well done, and especially commends the high standards of statistical technology evidenced in the publications of the bureau.

And, be it further resolved that the American Statistical Association felicitates its former President, Dr. Wesley C. Mitchell, for his great work as Director of Research of the National Bureau of Economic Research.

2. Resolved that the officers and members of the American Statistical Association express their sincere appreciation of the devoted services rendered under most trying circumstances during the past year and their gratitude to its Secretary-Treasurer, Lester S. Kellogg, for his invaluable contribution to the development and welfare of the Association.

3. Resolved that the officers and members of the American Statistical Association express their gratitude to the Secretary of Labor and the Acting Commissioner of Labor Statistics for their contribution to the development and efficacy of statistical science by sharing with the Association the services of Lester S. Kellogg.

4. Whereas, despite difficult travel and other conditions, the Annual Meeting of the American Statistical Association has been successful from every standpoint,

Therefore, be it resolved, that the special thanks of the Association are hereby extended to the members of the Cleveland Committee on Local Arrangements, particularly to Mr. E. A. Stephen, Mr. John W. Love, Miss Rose Vormelker, as well as to their associates and to the Cleveland Convention Bureau for their generous and unflagging assistance and cooperation, without which this Annual Meeting could not have been held.

5. Whereas, the Program Committee has assembled an outstanding group of speakers at short notice,

Therefore, be it resolved, that the Association takes this means of thanking the members of the Program Committee for their effective contribution to the success of this meeting.

6. Whereas, during 1945, the American Statistical Association has made further substantial progress in all its activities,

Therefore, be it resolved, that the Association hereby records its praise and thanks for the unselfish and successful efforts of its officers, its extremely capable staff, its chapter officers and committee members.

The resolutions were passed unanimously.

Helen M. Walker, Chairman of the Nominating Committee, reported that the following persons were nominated for officers of the American Statistical Association for 1946:

President: ISADOR LUBIN, Commissioner of Labor Statistics
Vice-Presidents: F. L. CARMICHAEL, University of Denver
DOROTHY SWAINE THOMAS, Giannini Hall, University of California
S. S. WILKS, Princeton University
Directors: (For the terms expiring at the Annual Meeting in 1948)
WALTER A. SHEWHART, Bell Telephone Laboratories
SAMUEL A. STOUFFER, Army Service Forces
Secretary-Treasurer: LESTER S. KELLOGG

The Secretary reported that he had received no nominations by petition and the slate of the Nominating Committee was unanimously elected.

Isador Lubin, newly elected President of the Association took the Chair of the meeting and Willard L. Thorp, Chairman of the Committee on Structure, reported on the draft constitution prepared by his committee.[3]

Rufus S. Tucker, proposed the following Amendment to the By-Laws of the Constitution:

> "There shall be a Committee on Professional Standards, composed of five Fellows appointed by the Board of Directors, whose duty shall be to recommend to the Board of Directors such actions and procedures as may tend to maintain and enhance the reputation of the Association and of the statistical profession for veracity and accuracy."

Dr. Lubin suggested referring the amendment to the Board of Directors for action and Dr. Tucker accepted the proposal.

The meeting was adjourned.

LESTER S. KELLOGG, *Secretary*

[3] See report of Committee on Structure printed in this issue.

Report of the Board of Directors

The year 1945 has been another year of steady advance on a wide statistical front.

With the coming of peace, we will gradually be able to travel again, to have meetings of the whole Association and its committees, and to engage more actively in the publication programs which are so essential to the growth and development of the profession of statistics. The signs of this development have been important in the activities of the American Statistical Association in 1945.

Meetings. Soon after the defeat of Japan, the Board of Directors and Officers decided to plan an annual meeting of the Association at Cleveland, Ohio between January 24 and 27, 1946, at the same time as the annual meetings of the Institute of Mathematical Statistics, the American Economic Association, the Econometric Society, and the American Marketing Association. The members of the Program Committee, the Officers and members of the Cleveland Chapter, the District Representative, and many members of the Association immediately directed major attention to the development of a program and to the arrangements of physical detail for the meeting. The annual meeting is the first of the whole Association's membership since December 1941—the first in a break of more than 4 years. At this same meeting, the Board authorized the appointment of a committee to prepare programs for meetings to be presented at the sessions of the AAAS at St. Louis, Missouri, March 27, 28, 29, 1946.

It is the sincere hope of the Board of Directors that there will never be another catastrophe of such calamitous proportions as to stop major activities of the nation's professional groups.

Operating under a Constitution which did not provide for such restrictions as the war imposed, the Board of Directors found it impossible during the war to carry on certain kinds of Association activities satisfactorily. At an Annual Business Meeting of the membership, called by the Board of Directors at the time of the regional meetings in Washington, D. C. between December 27 and 29, 1944, a proposal for revision of the Constitution was passed which will make it possible for the membership to vote on issues submitted by the Board in the interim periods between annual meetings.

The Board of Directors, as in other years, has met regularly, at times for extended sessions of as long as 2 days to face the various and new problems of interest to the statistical profession.

Chapters. The Chapters of the Association have had valuable programs of meetings during the year. Reports of these meetings, which have been published in the ASA *Bulletin*, have indicated that the Chapters are sharply conscious of the problems facing the development of data, techniques, interpretation and professional stature. A new Chapter was chartered in Seattle, Washington, bringing the total number of Chapters to 24 at the year's end. Inquiries from several other centers of population indicate that additional petitions for Chapter charters may be expected in 1946.

Publications. Following the resignation of Dr. Frank Ross as Editor of the JOURNAL, the Board of Directors established a new Editorial Board consisting of a Managing Editor of all Association publications, a Technical Editor of the JOURNAL, a Review Editor, and six other members. Twelve Editorial Collaborators to assist the members of the Editorial Board, both in stimulating the writing of papers and in refereeing and reviewing articles, have also been appointed. The names of members working on these groups are listed at the beginning of this JOURNAL. The Editorial Board has held two meetings during the year to lay plans for the Board's activities and procedures. Editorial policy was reviewed and a restatement of it has been proposed which will soon be presented in the ASA *Bulletin;* a restatement of the JOURNAL's book review policy was presented in the ASA *Bulletin* in August, 1945.

Plans are being made to devote one issue of the JOURNAL in 1946 to "The Role of Statistics in the War."

At its meeting on December 29, 1944, the Board of Directors approved a budget for 1945 which made it possible to introduce the *Biometrics Bulletin*, publication of the Biometrics Section. The *Biometrics Bulletin* is edited by the Biometrics Section Editorial Board, and with the assistance of the Secretary's office in production has successfully completed the first year of six bimonthly issues. Through loyal support of the membership of the American Statistical Association and several membership campaigns, the total distribution of the *Biometrics Bulletin* numbered 1214 as of December 31, 1945.

The Membership Directory, giving more detail about members and more classifications than any previous American Statistical Association Directory, was issued with the December 1945 issue of the JOURNAL. Plans are being made to issue a supplement containing names and addresses of all new members in each December issue of the JOURNAL.

The ASA *Bulletin* has continued to be issued four times a year.

Committees. The war continued during 1945 to take a very serious toll in terms of restrictions on committee activity. Heavy individual wartime responsibilities and restricted travel and hotel facilities made a wide range of committee activity impossible. In spite of these difficulties, however, there has been very important committee activity and substantial contributions therefrom to statistics.

The following standing committees have continued activity and with the return to peace expect opportunity for greater activity in 1946: Committee on Census Enumeration Areas, The Census Advisory Committee, and the Committee on Occupational Classification.

The Committee on Fellows took the Directory personnel forms as a basis and have devised a new procedure for reviewing the accomplishments of members who should be considered for election as Fellows. The committee has also completed a report which was published in the November issue of the ASA *Bulletin.*

The special committee which was appointed in 1943 by President Goldenweiser at the request of Secretary of Labor Perkins was discharged with the thanks of the Board for the excellent job it had done.

The Association's Committee on Education and Training of Statisticians has progressed less far than was hoped, due to the resignation of its chairman.

Upon special assignment, a committee working with a similar group from the Institute of Mathematical Statistics drafted a "Description of the Profession of Statistics," for use of the National Roster of Scientific and Specialized Personnel of the War Manpower Commission, as a guide for returning servicemen. Parts of this statement have been widely used in statements published by the Army and Navy.

The special Committee on Structural Organization early in 1945 invited representatives of a number of professional societies to meet to discuss the possibility of revising the Constitution of the American Statistical Association, to make it a society that could more effectively represent the interests of statistics in all substantive fields. The representatives of the other societies agreed that the proposal was good and asked the Association representatives to proceed with a draft Constitution and to present the draft to a subsequent meeting of the group. The draft was presented to the group late in the year. Suggestions for revision were received and incorporated in the draft Constitution which was presented to the annual meeting and will be distributed to the membership in 1946.

A special Committee was appointed to work jointly with a similar committee of the American Economic Association on the preparation of a Source Book of Economic Statistics. The committee was composed of the following: Walter Mitchell, Jr., J. Frederic Dewhurst, Philip M. Hauser, and Theodore O. Yntema.

Problems of the utilization and disposition of government war records have attracted a great deal of attention in the latter part of 1945. A special committee composed of Lester S. Kellogg, Morris A. Copeland, William R. Leonard, and Aryness Joy Wickens was appointed to work on these problems and to represent the American Statistical Association in similar efforts which may be made by other professional associations.

At the request of Secretary of Labor Frances Perkins, an Advisory Committee to the Bureau of Labor Statistics to review the Bureau's projected employment statistics program was appointed. This committee has worked diligently and soon will present a detailed report to the Labor Department. The committee was composed of: S. S. Wilks, W. A. Berridge, Robert Burgess, O. A. Fried, and M. I. Gershenson.

Employment. During 1945 the Secretary's office has continued to provide a skeleton type of placement service for statisticians. Plans for expansion of such service are still in a discussion stage.

Henry B. Arthur	E. Grosvenor Plowman
Chester I. Bliss	Walter A. Shewhart
Lester S. Kellogg	Willard L. Thorp
Simon Kuznets	Helen M. Walker

Report of the Secretary

The Secretary's activities during 1945, as in all other years, are closely related to every phase of the Association's program. Since the beginning of the annual publication of a summary of the work of the Board of Directors, in 1938, the Secretary's report has dealt mainly with membership changes.

During 1945, membership in the American Statistical Association increased by 444, bringing the total as of December 31 to 3,480. This growth during the last of the war years if of great importance as an indication of the potential interest in the Association's development. It is fitting for the Secretary at this time to provide more information than is customary on the Association's membership over an extended period.

Listed below are the figures on total membership at the end of specified years. The complete story is not told by these figures because there have been several periods of decline, especially during the depression years of 1933 to 1935, and again in 1941 and 1942:

1914:	700
1918:	800
1935:	1,750
1939:	2,500
1945:	3,480

The 1945 total is composed of the following classes of members:

Honorary Members	15
Fellows*	123
Regular Members	3,342
Total Membership	3,480
Corporate Members	4

One hundred sixty five members were still in the armed forces of the United States at the end of the year. There were 61 resignations and 190 members were removed from the active rolls for failure to pay dues.

Donald R. Belcher, Alfred Cahen, Erwin A. Gaumnitz, David H. McAlpin, Kenneth A. Norton, Millard H. Pryor, Winfield W. Riefler and Elmo Roper were elected to life membership during 1945, bringing the total Life members to 48.

The death of the following members was recorded during the year: Edwin F. Gay and. E. W. Kemmerer, *Fellows and Senior Members;* David Friday, *Fellow,* Richard T. Ely and J. H. Hollander, *Senior Members;* William W. Adams, C. M. Barnes, Walter W. Cooper, Sedley A. Cudmore, Lawrence Flinn, Lyonel C. Florant, Harry L. Gale, Dorothy F. Holland, George E. Mason, Norman Merriam, John F. Normano, E. F. Perkins, John B. Shephard, Lewis R. Soffer, Arthur E. Thompson, Edith Wood, and Leo Day Woodworth, *Regular Members*, and Delphine P. Harriman, *Associate Member.*

LESTER S. KELLOGG, *Secretary*

* This figure does not include the twelve fellows elected at the Annual Meeting in January 1946.

Report of the Treasurer

The year 1945 has followed the general pattern of 1944 and 1943. The budget has had to be kept continuously fluid.

The 1945 budget as approved by the Board of Directors planned for an income of $21,385 and expenditures of $25,230. As the year ended, income totaled $24,436 and expenditures $25,998, reflecting a deficit about one-quarter as large as that planned. The major reasons for the increase of actual income over planned income was the success of a continuous membership drive, of increased subscriptions, and the income from the *Biometrics Bulletin* which had not been estimated.

Larger expenditures than those planned were due mainly to increased costs of printing the JOURNAL and the greater than estimated cost of printing the *Biometrics Bulletin*. The increase in cost of the JOURNAL was due primarily to additional expenses involved in shifting the editorship. Greater than anticipated expenses for the *Biometrics Bulletin* were due to the large printing of early editions in order to obtain wide initial distribution. The effects of efforts expended on membership and subscription drives were reflected in additional office expenses, which were considerably higher than planned.

At the current rate of expansion of activity and growth in membership, it is likely that the 1946 budget of income and expenses will see another rise over the 1945 budget and it is hoped that this budget will likewise have to be kept continuously flexible and expansible.

LESTER S. KELLOGG, *Treasurer*

Report of the Auditors

To the Board of Directors of
American Statistical Association

We have examined the attached financial statements of American Statistical Association relating to the year ending December 31, 1945. Our examination was made in accordance with generally accepted auditing standards applicable in the circumstances, and included such tests of the accounting records and other supporting evidence and such other procedures as we considered necessary.

The recorded cash receipts for the year were traced to the deposits shown on the bank statements and the amounts for dues and subscriptions were tested with the membership and subscription records. The paid checks and relative vouchers were inspected in support of the cash disbursements for the year. The bank balances were reconciled with certificates obtained direct from the depositaries and the cash on hand and the securities owned at December 31, 1945 were verified by inspection. We did not check the membership and subscription records in detail or make any independent verification of the inventory of old JOURNALS, the office records of which are based in part on data assembled in prior years, no recent physical inventory having been taken.

The life membership reserve is computed on the basis of the combined annuity table of mortality with assumed interest at 4% per annum and an assumed annuity of $5.00 per life member, in accordance with a resolution of the Board of Directors on March 31, 1936. The amount treated as income in each year represents the excess of the reserve at the beginning of the year plus interest for the year and new life membership receipts over the required reserve at the end of the year.

In our opinion, the accompanying statements present fairly the position of American Statistical Association at December 31, 1945 and the results of its operations for the year in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

PRICE, WATERHOUSE & CO.

Washington, D. C.
March 6, 1946

AMERICAN STATISTICAL ASSOCIATION
BALANCE SHEET

Assets	December 31, 1945	1944
Cash in bank and on hand	$11,383.58	$10,178.04
Accounts receivable	80.04	289.53
Investments:		
United States Savings Bonds, Series D, at redemption value	5,749.00	5,615.00
Stocks, at cost, (at market quotations $6,875 and $5,160, respectively)	5,793.50	5,793.50
Inventory of old JOURNALS, at approximate cost	1,807.56	1,683.32
Furniture and equipment, at cost less depreciation	828.20	716.52
	$25,641.88	$24,275.91
Liabilities		
Accounts payable	$ 1,772.07	$ 1,247.16
Deferred income (collections applicable to subsequent year):		
Dues	$ 6,570.00	$ 5,295.72
Subscriptions	3,064.85	2,711.57
JOURNAL advertising	183.76	176.40
	$ 9,818.61	$ 8,183.69
Net worth:		
Life membership reserve	$ 3,201.75	$ 2,614.83
Centenary Sustaining Fund, per statement	6,255.25	6,114.21
Surplus, per statement	4,594.20	6,116.02
	$14,051.20	$14,845.06
	$25,641.88	$24,275.91

American Statistical Association
Income Statement

	Year ending December 31, 1945	1944
Income:		
Dues—current year	$15,419.50	$12,902.75
Dues—prior years	101.75	47.75
Life memberships	317.67	239.08
Subscriptions	4,588.91	3,909.00
Advertising	897.86	949.59
Reprints	479.23	974.79
Journal sales	647.35	1,267.35
Index to the Journal, sales		10.00
Special publications		56.33
Biometrics Section income	1,587.83	
Annual meeting		322.86
Miscellaneous	103.16	12.50
Dividends and interest (after deducting $104.59 in 1945 apportioned to life membership reserve)	277.11	179.72
	$24,420.37	$20,871.72
Expenses:		
Journal—printing, mailing and reprints	$ 6,074.92	$ 5,068.63
Bulletin	717.02	672.51
Salaries and wages	12,157.14	11,489.62
Unemployment compensation tax	11.37	10.96
Rent	1,020.00	834.00
Office supplies, printing and mimeographing	1,285.93	680.66
Postage	871.39	678.65
Telephone and telegraph	247.44	296.41
Travel expense—officers	276.72	523.11
Biometrics Section expenses	2,570.49	91.93
Directory expense		85.00
Storage of old Journals	72.00	72.00
Cost of old Journals sold	62.16	154.88
Depreciation of furniture and equipment	146.15	126.44
Miscellaneous	429.46	361.00
	$25,942.19	$21,145.80
Balance, loss, carried to surplus	$(1,521.82)	$ (274.08)

AMERICAN STATISTICAL ASSOCIATION
SURPLUS STATEMENT

	Year ending December 31, 1945	1944
Balance at beginning of year	$6,116.02	$6,400.10
Deduct—Excess of expense over income for the year, per income statement	$1,521.82	$ 274.08
Appropriation to Centenary Sustaining Fund of amount equal to net proceeds from sales of Index to the JOURNAL		10.00
	$1,521.82	$ 284.08
Balance at end of year	$4,594.20	$6,116.02

CENTENARY SUSTAINING FUND

Balance at beginning of year	$6,114.21	$5,670.81
Add—Amounts received from contributors on pledges	$ 30.00	$ 327.50
Interest received on bank savings account and increase in redemption value of securities	106.54	105.90
Net proceeds from sales of Index to the JOURNAL	4.50	10.00
	$ 141.04	$ 443.40
Balance at end of year	$6,255.25	$6,114.21

Committee on Structure

Although the Committee on Structure unfortunately reached a high coefficient of scatteration during the last year, it has substantial progress to report. At its request, the Board of Directors issued invitations to American Marketing Association, American Public Health Association (Vital Statistics Section), American Standards Association, Econometric Society, Institute of Mathematical Statistics, National Quality Control Society, New York Society of Security Analysts, Population Association, Psychometric Society, and the Sociometric Institute, Inc. to attend a conference to discuss the overall problem of organization in the statistical field. For some years, there has been a tendency for specialized groups within the general field of statistics to set up their own specialized organizations. In spite of the substantial amount of common interest, there has been little relationship among these groups, other than from interlocking memberships. It is obvious that this tendency was in substantial degree the result of the failure of the American Statistical Association to meet the needs of these specialized groups.

The conference came to the conclusion that the time has come to bring these various organized activities in the statistical field into a closer relationship and to provide machinery whereby hereafter the satisfaction of specialized needs would be given substantial encouragement. Some sort of central body seemed necessary to act as spokesman for all statisticians, to eliminate unnecessary duplications in costs and energy exhaustion, to integrate and cross-fertilize meetings, programs and publications, and to develop organized activity in certain areas not presently occupied. It was felt that the American Statistical Association as the oldest and largest organization might well take the lead and develop a program which would be such that these other organizations might work more closely with it while not losing their autonomy in directing their own affairs.

After considerable study, the Committee has come to the conclusion that this aim can best be accomplished through a substantial reorganization of the American Statistical Association. In connection with this, provision should be made for the recognition of associate societies and affiliated societies. An associate society would be one concerned with statistical method or the statistical aspects of some specific subject-matter field. An affiliated society would be one interested in statistics but not as a matter of primary concern. Both associate and affiliated societies would be given substantial participation in the government of the American Statistical Association, and the members of associate societies would receive a regular bulletin designed for statisticians in all fields.

The reorganization of the American Statistical Association involves its internal structure as well as its foreign relations. Proposals are that there be a responsible governing body known as the Council, which will consist of representatives of associated and affiliated societies, members elected by regional groups of chapters, the Board of Directors and the officers—perhaps thirty individuals. There would be provision providing for referenda, but in general the Council would be the legislative body. The President and Board members

would be elected by the Council. The Committee has also considered at some length the problem of chapter requirements, the necessity for increasing dues, the desirability of designating a President-elect, etc., etc.

By the end of the year, the Committee had completed a draft of a revised Constitution and By-laws. It is hoped that these can be discussed during the spring at various chapter meetings, and that action on the proposals can be taken early enough to permit the new program, if and as approved, to go into effect in 1947.

WILLARD L. THORP

The Committee on Fellows.[4] The Board of Directors prior to January 1, 1945 requested the 1945 Committee on Fellows to review the whole problem of Association honors. Because the question of honors in the last analysis must be based upon the objectives sought in conferring those honors and because these, in turn, are dependent upon the objectives sought in the new Constitution, the work presented in this report can be considered only suggestive. It is recommended, consequently, that the report presented herewith, if found acceptable, shall be passed on to the Committee on the Constitution so that plans may be adopted which will be consistent with the objectives of the new Constitution.

There are at least four reasons in favor of honors which provide objectives for a plan. These reasons are:

1. A gesture of appreciation or of commendation which is official in character and granted in recognition of work of a high quality well done.
2. A device to stimulate interest in the work of the Association so that members honored will feel themselves to be more definitely an integral part of the Association.
3. An obligation to the general public since in the growing importance of statistical work it is desirable that the public look toward some group for leadership. Honors provide a means of securing such leadership.
4. A device for promoting international good will through a definite honor conferred upon a citizen of a foreign country.

It should be noted that success in these objectives, or in others which may be included, is dependent upon a well organized, aggressive Association. Such an organization should accept the responsibilities which its position implies toward problems which have now come to be of national importance in a postwar society.

In the material which follows, the recommendations are first stated. The presentation of recommendations is followed by reasons for making them.

Recommendations

I. Fellows

It is recommended that

a. Election to class of membership of the Association known as Fellows

[4] Mr. Henry B. Arthur was appointed by President Walter A. Shewhart to the Committee on Fellows on December 11, 1945 to serve for the term January 1946 through December 1950.

shall represent a distinguished honor for work of high quality in statistics.

b. Fellowship shall be limited to citizens of the United States and Canada.

c. The method of their election shall be as provided in the present Constitution.

d. Their number shall be relatively small and limited to 200 members instead of the present limit of 150.

e. The Fellows be used in various special capacities on behalf of the Association and be more directly integrated with its activities.

II. Honorary Members

It is recommended that

a. This class of membership be limited to citizens of foreign countries.

b. Their election shall be accomplished through a Nominating Committee of three Fellows who shall serve for a term of three years. Upon nomination by the Committee on Honorary Members, final election shall be by the Board of Directors, and notification made by the President of the Association in collaboration with the Chairman of the Committee.

c. The number shall not be greater than 25.

III. Special Prizes

It is recommended that

a. American Statistical Association Awards be established for members who have not reached their 32nd birthday on January 1 of a given year.

b. The Awards are to be made at the Annual Meeting.

c. Three Awards are to be conferred for not more than three outstanding papers published during the two years preceding each annual meeting. One of these papers is to be in statistical theory, one is to be an application of statistical methods and the third may be either of these types or a combination of them. No awards need to be granted if papers of sufficient quality have not been published.

d. The Awards consist of a prize of $100 and a Certificate.

e. A member shall not be eligible for a second Award.

f. No Fellow is eligible for an Award.

g. The Fellows should be polled annually for lists of distinguished papers.

h. Awards should be made by a committee of three Fellows on Awards. This committee should be organized in the same way as the Committee on Honorary Members.

IV. Distinguished Lecturers

It is recommended that

a. There be chosen each year an annual Lecturer who should address the Association at the time of the Annual Meeting, and other lecturers who, in the course of a year, should speak before the chapters.

b. The Annual Lecturer and the Chapter Lecturers may be selected from any group of the Association membership.

c. The Lectures together with the Presidential Address shall be published by the Association early in the year following each Annual Meeting.
d. The Chapter Lecturers, in general, shall be selected from sections of the country at some distance from the Chapter at which the lectures are to be given. To facilitate this work, funds should be provided to cover travel expenses of the Lecturers.
e. A committee of the Fellows appointed by the Board shall arrange for these Lectureships. The Secretary of the Association shall be a member of this Committee.

V. Finances

It is recommended that efforts be made to finance these recommendations through special funds.

Discussion

I. Fellows

The basic problem of the Fellows is two-fold: (1) whether to represent a group selected to confer an honor for accomplishment, or (2) whether they are to be selected merely as a professional class of the Association. Regardless of the group which they are to represent there will always be differences of opinion in regard to the criteria used and the wisdom of the Committee's selection. Nevertheless, it is believed on the basis of past experience that the selection can be made with a reasonable degree of precision. If the Fellowship is to represent a distinguished honor in terms of relatively long accomplishment, clearly brilliant younger members are likely to be passed by temporarily. With this in mind, the proposal of special prizes and Distinguished Lectureships has been suggested as a means of recognition by the Association for a larger group. There is the further condition that the older active members of the Association are likely to be heavily loaded with important work. If the Association can command their interest for work in perpetuating their own number and in acting as members of committees in connection with other honors, their importance in the work of the Association will be definitely enhanced.

As judged by the replies to the long questionnaire sent to the Fellows over a year ago, there is not the slightest doubt about the very real interest which many Fellows have in the Association. It might very well happen, consequently, that they could be polled from time to time in regard to other important problems or policies of the Association. Thus they would act as an informal advisory Senate for the Association officers.

There is no objective line of reasoning which will lead uniquely to the limiting number for Fellows. A review of the early 1945 Association membership, however, indicates the following facts: If the criterion of two or more check marks in the right-hand column of the card shown on page 45 of the November, 1945, *Bulletin* be used, it will be found that including Fellows there will be listed some 600 or 700 individuals. This is about 25% of the membership of the Association. A limit of 250 would represent about a third

of these. In other words, about a third of the members who have secured recognition either in Association activities or in publication of articles would be the limiting number for the honor of Fellowship. Whether this number would be desirable in the light of more critical evidence to be obtained in the years ahead is unknown. Whenever a condition of nonbalance occurs, however, the Constitution could again be amended.

The present method of determining the Committee on Fellows is wise and should be continued. It leaves the Committee completely free from influence of current officers. It provides the maximum of independence and so lends quality as well as dignity in the conferring of this honor.

II. Honorary Members

A poll of the Fellows early in 1945 showed almost unanimous support for the decision that the honorary members should be citizens of foreign countries exclusively. There was a difference of opinion as to how the election should be carried through. Nevertheless, the weight of the thoughtful comments was in the direction of the difficulty of identifying outstanding statisticians in foreign countries and, consequently, of the belief that a continuing committee organized like the Committee on Fellows and reporting to the Board of Directors would be the most effective way of accomplishing the result. Here is another extremely difficult but important problem for the Fellows to undertake.

III. Special Prizes

Much earnest comment has been received from the Fellows in regard to the necessity of honoring scholarly work of the younger members of the Association. Thoughtful comments tended to imply that the Fellows will, as a rule, be elected from among the older members of the Association who, through years of effort, had built for themselves an outstanding reputation. There was the need, consequently, for some means to confer honor upon the younger members of the Association and, in so doing, to stimulate their interest in professional work and in the Association. It was with these thoughts in mind, that the recommendations for the special prizes were prepared. Emphasis should be placed upon the intent to secure a breadth of interest in the papers and upon the use of a two-year period. This time interval obviously will result in a one-year overlap. Intention is to provide for possible recognition of both of two papers which happen to have been published in a given year on, for example, The Theory of Statistics. One paper might be recognized one year and the other at the end of the following. Another reason is to avoid excluding authors who happen to have articles appearing in December journals. The cash award is large enough to be of importance to most young men and the Certificate probably would be cherished as the first of a possible series of honors to be won during a lifetime of work.

The ineligibility of Fellows is deliberate since the intent of the prize is to discover new talent. It would be hoped, of course, that prize winners in some future year would be made Fellows.

IV. Distinguished Lecturers

Several objectives are present in this recommendation. The object of the Distinguished Lecturer at the Annual Meeting is to bring recognition to members of outstanding ability commonly in the age group between 30 and 45 who have not been elected Fellows. The intent is that the Association will be honored in the act of honoring them. On the other hand, intent of the Chapter Lectureships is to stimulate the work of the chapters and at the same time to confer directly an honor upon any member of the Association who may be chosen to deliver such a lecture. It will be noted that no special cash award of any kind aside from the distinction of Distinguished Lecturer has been included. The suggestion that transportation expense be provided is done with the deliberate hope that Lecturers can be interchanged between Chapters as widely separated as New York and Los Angeles, or Washington, D. C., and Seattle.

THEODORE H. BROWN, *Chairman*
LOWELL J. REED
JOSEPH S. DAVIS
ARYNESS JOY WICKENS
HAROLD HOTELLING

The Biometrics Section. Following approval by the Board of Directors of the American Statistical Association, the main project of the Biometrics Section in 1945 has been the *Biometrics Bulletin.* The Editorial Committee for the Bulletin consists of G. M. Cox, Chairman, C. I. Bliss, W. G. Cochran, F. R. Immer, H. W. Norton, L. J. Reed, G. W. Snedecor and Sewall Wright. Complimentary copies of one or both of the first two numbers and an invitation to join the Section were sent to all members of the parent Association and to other potential members. The response has been encouraging. As of December 31, 1945, 1079 members and associate members and 135 subscribers were receiving the Bulletin.

The *Biometrics Bulletin* has appeared bi-monthly, beginning in Februaary. The first volume, which totals 92 pages, would have required nearly twice as many pages in the format of the *Journal of the American Statistical Association.* In order that the volume would coincide with the calendar year, the Bulletin started without a backlog of material. The Section is indebted primarily to our very able Editor for filling the Bulletin despite many difficulties, and to the Secretary's office of the Association for the production and distribution phases. As the Bulletin becomes better known and meetings are resumed, we can look forward to a steady growth both in its influence and size.

Membership in the Section on December 31, 1945 comprised 862 members and 217 associate members, the former belonging to the parent Association and paying annual dues of one dollar, the latter two dollars. Fields of interest represented in the Section have been tabulated from data on 769

individuals. Of these, 65.8 percent reported an interest in some branch of biology with medical science the most frequent, 16.1 percent an interest in meteorology, chemistry, mathematics or industry, and 18.1 percent in the social sciences. Expenses of the first year not covered by dues and subscriptions have been absorbed by the parent Association or contributed by members of the Editorial Committee and by the North Carolina State College. The parent Association has been compensated in part by new members who have joined both the Section and the parent Association. We should look forward, however, to the necessity of increasing dues in 1947.

The last sessions of the Biometrics Section were held at the annual meeting of the Association in December 1944, none having been held in 1945 due to the limitations on travel. In 1946, two sessions are scheduled for the Cleveland meetings in January including one sponsored jointly with the Institute of Mathematical Statistics. A joint session in the week of March 11 at Atlantic City is being arranged with the American Society for Pharmacology and Experimental Therapeutics. Other sessions are being planned for the meetings of the A.A.A.S. in St. Louis during the week of March 25 by a special committee under the chairmanship of H. C. Fryer. Two of these are deferred meetings from 1945.

The Biometrics Section was represented at Inter-Society conferences on February 10 and December 8 for coordinating the activities of professional organizations interested in statistical method. These plans provide for the growth of sections into self-supporting associate societies integrated into an over-all program. In line with this development, a special committee of which A. E. Brandt is chairman will report a draft constitution to the business meeting of the Section in Cleveland. If this constitution is adopted, the Section will become the "Biometrics Society, an Associate of the American Statistical Association."

CHESTER I. BLISS, *Chairman*

Committee on the Employment Statistics Program of the Bureau of Labor Statistics. This Committee was established by the Association in May, 1945, at the request of the Secretary of Labor, to review the proposed expanded employment statistics program of the Bureau of Labor Statistics. The mandate of the Committee is limited to the Department of Labor and to current statistics as distinguished from conjectural forecasts. During the summer and fall, individual members of the Committee have had numerous conferences and discussions with officials and technical experts of the Bureau of Labor Statistics. A large number of documents pertaining to procedures for obtaining estimates of employment in an expanded program have been received from the Bureau of Labor Statistics and are being studied by the Committee.

Members of the Committee have also discussed sources of information, procedures, and other matters relating to the problem of estimating employment with members of the Committee on Labor Supply, Employment

and Unemployment Statistics and with individuals in various bureaus and agencies of the government. Reports and other documents from these agencies are under study by the Committee.

A meeting of the Committee, together with representatives of the Bureau of Labor Statistics, Bureau of the Census, and Bureau of Economic Security, was held in New York on September 11, 1945, at which time various questions and topics on procedures being used or contemplated in the enlarged employment statistics program of the Bureau of Labor Statistics were discussed.

It is anticipated that a preliminary draft of a report now under preparation will be completed within a few weeks.

W. A. Berridge
R. W. Burgess
O. A. Fried
M. I. Gershenson
S. S. Wilks, *Chairman*

Committee on Census Enumeration Areas. The Committee on Census Enumeration Areas held its annual meeting at a luncheon session on Friday, January 25, 1946, at the Carter Hotel in Cleveland, Ohio.

Speakers at this session were Esther M. Wright, Howard G. Brunsman, Clarence E. Batschelet, and Howard Whipple Green. The papers included a review of current activities of the tracted cities in promoting census tract use, plans of the Bureau of the Census for 1950, practical considerations in extending tracted areas beyond city limits, and techniques utilized in popularizing census tract use in Cleveland.

The meeting adjourned to the office of the Chairman of the Committee where there was an exhibit of census tract street indexes and maps, published studies incorporating census tract data, and numerous maps and charts showing the distribution of social and economic characteristics of the population by tracts. These materials included the published works from other cities as well as Cleveland. A practical demonstration of preparing spot maps and overlay maps was also given.

The meeting and exhibit were enthusiastically attended by nearly 100 persons.

During the year a summary of the questionnaires returned by the Key Persons was completed and published, 29 pages. This report includes a list of Key Persons and Census Tract Committee members for each city, facts concerning census tract maps and census tract street indexes for each city, and a list of the most important users of tract data.

A complete set of the papers presented at the 1944 December meeting, 21 pages, was also distributed to all Key Persons and others interested in census tract use.

The Committee is planning to publish a manual on census tract use during 1946.

A third of the Census Tract Key Persons left their cities during the past year but the Chairman is pleased to report that replacements have been found for all but five cities. There is definite evidence of more active interest developing currently in census tract use. The Bureau of the Census reports that its supply of 1940 tract publications has been exhausted. There has been considerable correspondence with Key Persons concerning the development of adequate census tract maps and street indexes, establishment of census tract committees, and extension of tracts in suburban areas. Several conferences on these problems have also been held with Key Persons.

The Committee wishes to express its appreciation to the Bureau of the Census for its cooperation during the year. Members of the Consulting Staff of the Vital Statistics Division have made surveys of census tract use in 20 cities as well as giving the Chairman assistance in his Committee work.

Respectfully submitted,
HOWARD WHIPPLE GREEN, *Chairman*
C. E. BATSCHELET
DOCTOR W. THURBER FALES
DOCTOR ERNEST M. FISHER
MRS. SHIRLEY K. HART
DOCTOR PHILIP M. HAUSER
DOCTOR VERGIL D. REED
DOCTOR LEON E. TRUESDELL
DOCTOR LENT D. UPSON

Joint Committee on Occupational Classification. During the past year, the Joint Committee on Occupational Classification of the American Statistical Association and the Division of Statistical Standards of the Bureau of the Budget and its technical subcommittee have been concerned with taking account of the effects of the war on occupational classification systems. This has involved the incorporation of new job titles or the reclassification of old titles necessitated as a result of war developments. Another specific problem on which considerable progress has recently been made is the translation of military classifications into their civilian equivalents. This work has facilitated the counselling and placement of veterans and of workers displaced from war industries as well as providing the basis for a better description of the occupational skills of the population in the post-war period.

The Bureau of the Census has initiated work on revising its Index of Occupations and the United States Employment Service has started a revision of its Occupational Directory. Both of these activities are long-term projects and all major classification differences arising in these two systems will be cleared through the Committee for settlement, as they have been in the past. This clearance is a continuing process and constitutes a review of the Convertibility List, which was developed by the Joint Committee on Occupational Classification in 1940 as the framework for standardization of occupational statistics.

In addition, requests for reclassification of occupations are received from the representatives of particular occupational or professional groups in the public and are considered by the Committee, with or without formal hearings. During the past year, agencies representing optometrists, chiropracters, and Christian Science practitioners have requested reclassification in the United States Employment Service and/or Census classification systems and the Convertibility List.

GLADYS L. PALMER, *Chairman*

Census Advisory Committee. The Census Advisory Committee of the American Statistical Association held only two meetings during the past year, one in April and one in November. However, from the point of view of content, the level at which the discussions were held and the problems discussed, these meetings were highly important. The appointment of a new Secretary of Commerce called for revaluation and restatement of the program of the Bureau of the Census which was reviewed and discussed to some length at the April meeting, covering not only the problems which the Bureau met in wartime but also the directions toward which the Bureau should point in the postwar transition period and in peace time. Some of these directions crystallized later in the 1947 budget request of the Bureau of the Census for the fiscal year 1947, and in order to cover this program remedial legislation was introduced into Congress. The bill which was later introduced as H. R. 4781 incorporated the suggestions which the Committee has been making over the past years and which it specifically urged in a resolution adopted in the November meeting.

In general, the program toward which the Bureau of the Census is pointing calls for benchmark censuses on a staggered basis with Agriculture and Population being taken simultaneously every five years in years ending in 0 and 5 and Manufacture and Business, also quinquennially, in years ending in 2 and 7, in addition a strong program of current data necessary for the study of economic and social data which are planned. The availability of such data would be very helpful in meeting the statistical needs of the nation. In addition to, the consideration of over-all program, topics discussed included the Census of Agriculture which was taken in the year 1945 and the organization of a Field Division in the Bureau of the Census. The latter was also the object of resolution at the November meeting, in which the Committee emphasized that the quality of statistical information as published can be no better than that obtained at the source. The existence of an adequate field staff experienced in field problems and methods would not only result in improvement in the current statistics programs now being developed but would also provide an essential nucleus around which the field staff for a major census could be organized. This would remedy many of the problems which exist by virtue of the temporary assembling and disbanding of key field personnel for the major censuses as has been the practice in the past. In addition, a continuing field organization can be effectively used on a serv-

ice basis for the collection of data for other Federal agencies. The concentration of field activity would result in a substantial improvement in Federal statistics in general and the Committee urged further study and action on this aspect of the problem.

The texts of the two resolutions follow:

Resolution on Census Bureau Program Adopted by the Census Advisory Committee of the American Statistical Association
November 10, 1945

The Census Advisory Committee of the American Statistical Association, having discussed with officials of the Bureau of the Census and with the membership of the American Statistical Association over a period of years major problems which face the Bureau of the Census, strongly urges the following conclusions and recommendations directed toward a balanced statistical program designed to be of maximum usefulness to the business community, to the government, and to the other consumers of statistical information. Such a program is urgently needed during the critical months and years ahead to effect an orderly transition from war to peace and to provide a sound factual basis for postwar adjustment.

(a) That in the coming year the Bureau of the Census be empowered to take Censuses of Manufactures and Business, a survey of the characteristics of the population on a sample basis, and a consumer income survey, and that it also be empowered to expand the present report of the labor force to obtain data for the major industrial areas.

(b) That the Bureau of the Census reschedule its basic census operations so as to achieve a better balanced program by conducting quinquennial censuses in lieu of the present unbalanced programs ranging from biennial to decennial censuses; and that these censuses be so spaced as to prevent undue administrative burden from being placed on the Bureau of the Census.

(c) That the Bureau of the Census be authorized to conduct its proposed program of current statistics including annual sample surveys and periodic monthly or quarterly reports necessary to provide timely information for current use.

It is the judgment of the Committee that both the immediate and long-run programs proposed by the Bureau of the Census would meet urgent needs of business, government, and other users of statistical information and that they should be authorized at an early date.

Resolution on Census Field Organization Adopted by the Census Advisory Committee of the American Statistical Association
November 10, 1945

One of the critical points in the collection of statistical information is the field interview, or the contact of the representative of the collection agent with the respondent. The quality of the statistical information as published can be no better than that obtained at the time of the enumeration. For this reason, the Census Advisory Committee of the American Statistical Association considers it extremely important that an adequate permanent field staff be maintained by the Bureau of the Census. Such a staff would become intimately acquainted with the problems and pitfalls of this important phase of statistical activity, would be useful in the collection of accurate data for the monthly report on the labor force, for annual surveys of retail trade and for other current sample studies. Such an organization would also provide an essential nucleus around which the field organization for the major censuses can be organized.

For these reasons, the Census Advisory Committee commends the organization of a separate Field Division within the Bureau of the Census to specialize in this activity. However, we believe that a specialized organization of this type can become most effective if it is also used on a service basis

for the collection of data for other Federal Agencies as well. This concentration of field activity in one specialized agency would result in a substantial improvement in the quality of other Federal statistics collected in the field, and the Committee strongly urges further study and action toward this end.

WILLIAM F. OGBURN, *Chairman*

List of Committees and Representatives for 1945

Committee on Fellows

Theodore H. Brown, *Chairman*
Lowell J. Reed
Joseph S. Davis
Aryness Joy Wickens
Harold Hotelling

Committee on Nominations

Helen M. Walker, *Chairman*
Frederick C. Mills
Stuart A. Rice

Committee on Investments

Henry B. Arthur, *Chairman*
E. Grosvenor Plowman
Willard L. Thorp

Budget Committee of the Board of Directors

Henry B. Arthur, *Chairman*
E. Grosvenor Plowman
Willard L. Thorp

Annual Meeting Program Committee

W. G. Cochran, *Chairman*
A. D. H. Kaplan
Lowell J. Reed

Biometrics Section Committee

C. I. Bliss, *Chairman*
Horace W. Norton, *Secretary*
Alva E. Brandt
William G. Cochran
Gertrude M. Cox
Churchill Eisenhart
Alfred J. Lotka
Hugo Muench, Jr.
J. Neyman
Lowell J. Reed
George W. Snedecor

Census Advisory Committee

W. F. Ogburn, *Chairman*
Murray R. Benedict
Donald R. G. Cowan
J. Frederic Dewhurst
Frederick F. Stephan
Willard L. Thorp

Committee on Census Enumeration Areas

Howard W. Green, *Chairman*
Clarence E. Batschelet
W. Thurber Fales
Ernest M. Fisher
Shirley K. Hart
Philip M. Hauser
Vergil D. Reed
Leon E. Truesdell
Lent D. Upson

Joint Committee on Occupational Classification

Gladys L. Palmer, *Chairman* and *Secretary*
Meredith B. Givens
Ida C. Merriam
Robert J. Myers
Caroll L. Shartle
Leon E. Truesdell

Committee on Sampling Surveys

S. S. Wilks, *Acting Chairman*
W. Edwards Deming
George W. Snedecor
Frederick F. Stephan
Alfred N. Watson
Theodore O. Yntema

Advisory Committee to the Bureau of Labor Statistics

S. S. Wilks, *Chairman*
W. A. Berridge
Robert Burgess
O. A. Fried
M. I. Gershenson

Committee on the Preservation and Destruction of War Records

Lester S. Kellogg
Morris A. Copeland
William R. Leonard
Aryness Joy Wickens

Committee on Preparation of a Source Book of Economic Statistics

Walter Mitchell, Jr., *Chairman*
J. Frederic Dewhurst
Philip M. Hauser
Theodore O. Yntema

Committee on Structure

Willard L. Thorp, *Chairman*
C. I. Bliss
W. G. Cochran
F. Leslie Hayford
Frederick F. Stephan
Helen M. Walker

Representative on the Board of Directors of the National Bureau of Economic Research

Frederick C. Mills

Members of the Social Science Research Council

Harold Hotelling
Frederick F. Stephan
Willard L. Thorp

Representative on the Council of the American Association for the Advancement of Science

Walter A. Shewhart

Representatives on the Joint Committee for the Development of Statistical Applications in Engineering and Manufacturing

Walter A. Shewhart
Churchill Eisenhart

Representative on the Sectional Committee on Standards for Graphic Presentation of the American Standards Association Sponsored by the American Society of Mechanical Engineers

Frederick E. Croxton

Representative on the Advisory Board of the American Year Book

Frank W. Notestein

Representative on the Advisory Committee to the Census Library Project

Richard O. Lang

Member of the American Documentation Institute

Lester S. Kellogg

BOOK REVIEWS

Edited by

OSCAR KRISEN BUROS
Rutgers University

Industrial Quality Control. Published bimonthly by The Society of Quality Control Engineers in cooperation with The University of Buffalo. $6.00 per year; $1.25 per issue; Vol. I (112 pp., 8½×11 in.) is available at $4.00 per set of 6 copies or $1.00 per copy. Edited by *Martin A. Brumbaugh* (Professor of Statistics, University of Buffalo). Editorial and publication office: Crosby Hall, University of Buffalo, Buffalo 14, New York. *Two reviews follow:*

REVIEW BY SEBASTIAN B. LITTAUER

Professor of Mathematics and Chairman of the Department
Newark College of Engineering

THE appearance in July, 1944, of the first issue of *Industrial Quality Control* served notice that "Quality Control" had come of age as a field of professional endeavor. As is well known, industrial quality control in its present sense dates from the early twenties when Shewhart began his original investigations which pointed the way to the use of statistical method. Before 1930 it would have been difficult to round up a dozen papers on statistical quality control. And in spite of a definite increase, thereafter, in the industrial use of statistical techniques in quality control, and in the publication of papers on the subject, in but relatively few industrial plants, up until the war, was there an awareness of control charts or sampling tables.

None the less, the advantages of statistical quality control had been so soundly established that during the war a program of intensive training in these techniques was carried on under the auspices of the Office of Production and Research Development and the U. S. Office of Education. The enthusiastic reception of this program was followed at many of the training centers by the organization of local quality control societies. From this nucleus of persons interested in the applications of statistical methods to industrial quality control has come the demand for a journal to serve their professional needs. To quote from an editorial in the first issue: " . . . Other publications are available for the presentation of statistical and mathematical developments of interest to quality control operators. Likewise the engineering approach is available. But between these two there is an open area of analytical quality control in industrial use. Into this open area *Industrial Quality Control* is projected as a service to the men and women who make the decisions from day to day in quality control departments."

That such service is being appreciatively rendered is attested to by a substantial group of readers among whom are more than seven hundred paid subscribers. The appearance of this bi-monthly periodical has stimulated the activities of many of the young quality control societies by publicizing their

activities and reporting fully on clinics, training courses and the like; by summarizing articles of interest appearing currently in other journals; by providing text reviews, news and notes, and other material usually found in the pages of a professional journal, and in the present case for the first time in a journal of their own, appealing directly to quality control operators. The early issues contained a comprehensive bibliography which must have been heartily welcomed by many a reader. In these and other ways *Industrial Quality Control* has been rendering valuable service to its readers and encouraging a sense of common professional interest among quality control workers.

The contributed papers, which are the substance of any technical journal, are rather difficult to appraise. All of them are concerned primarily with the statistical aspects of quality control. A good third of the papers deal with "indoctrination" and "general plant-wise operations," another third with sampling plans and the remainder with control chart applications or incidental techniques. Most of the papers are by persons engaged in industrial practice. Only a few of the papers are by seasoned writers in the field, and certain names intimately associated with the development of statistical quality control are not yet among the contributors. While most of the papers contain points of interest, in a number of the papers the results are invalidated because of weaknesses in the statistical theory used to obtain them.

A periodical is far more than the sum of its parts, and, indeed, is a living entity which can exercise a vital influence on the progress of the professional field which it serves. Founding such a journal is a worthy and formidable undertaking, while nurturing it to a mature status requires and merits support from all interested quarters. To the founders and editors of *Industrial Quality Control* genuine thanks are due and all good wishes for the full realization of their objectives.

REVIEW BY HOLBROOK WORKING
Professor of Prices and Statistics, Stanford University

THE ORIGIN and purposes of *Industrial Quality Control*, as stated in a "message from the President" and an "Editorial" in its first issue (July 1944) are well summarized in the following excerpts (sequence ours):

> More than a year ago the War Production Board through its Office of Production Research and Development launched a project to provide training in the use of analytical quality control to key personnel of plants producing war material[1]. . . . Early in this program an intensive course was given in Buffalo, September 11–18 [1943]. . . . On November 7 the graduates of this intensive course established the Society of Quality Control Engineers. . . . From this nucleus of 41 representatives of 15 individual industries, our membership has been augmented by graduates of three successive [part-time] classes in Quality Control, so that we now have an organization of 150 active members. . . . We propose through the medium of this publication to present

[1] On reconsideration, the author of this statement would doubtless want to acknowledge also the credit due the Engineering Science and Management War Training program of the U. S. Office of Education, which directly sponsored the intensive courses with which the OPRD assisted, and many part-time courses, also.

> to our membership, and the public, items of interest in Quality Control. . . . The content of each issue will be selected with the thought in mind that quality control operators in other areas face problems similar to those encountered in the Buffalo area. Accordingly materials appearing will, we hope, have more than local significance.

The objectives of the Buffalo society and of its publication were specified further in the second issue of the journal:

> Your officers are attempting to keep abreast of . . . developments by fostering two major programs: (1) the training of new quality control operators in courses offered at the University of Buffalo, (2) the publication of *Industrial Quality Control*. The magazine is designed to give you articles to show what other companies are doing, bibliographies to guide your reading concerning the use of control techniques in other parts of the country, tables to facilitate your work, and solutions of current problems presented by members of the society.

The first seven numbers of the journal were lithographed from well prepared typewritten copy on a page $8\frac{1}{2} \times 11$ inches. The first two comprised 16 pages each, including cover, and the remainder, 20 pages each. Volume II, Number 2, appeared in type, with 16 pages of the same size as before.

The articles in *Industrial Quality Control* fall mainly into three classes: (*a*) general discussions of the principles of quality control, and especially of statistical control; (*b*) reports on specific quality control projects; and (*c*) presentations of statistical theory and method applicable to quality control.

Generalizations have their merits, but one who has already read a little of the existing literature will not pause long over most of the articles which deal mainly in generalities. One, however, "Top Management Views Quality Control," by M. Herbert Eisenhart, President, Bausch and Lomb Optical Co., in the March 1945 issue, is an exceptionally thoughtful and interesting discussion of the broader aspects of quality control.

Among the papers that deal with specific applications of statistical control are two or three which include discussion of some broad problems of quality control, and in so doing are the more effective because they present conclusions in a setting of the conditions which validated them. Noteworthy on this account is "Growth of a Quality Control Department in a Canadian Ammunition Plant," by Douglas F. Brown, General Superintendent of the Technical Development and Control Department, Defense Industries, Ltd. (Cherrier Works), in the issue of November 1944. To go farther in the mention of individual papers on specific applications is scarcely possible here, for nearly every issue of the journal has contained one or two such papers of real merit, potentially useful to readers of diverse interests.

Papers and notes concerned with statistical theory and method in the early issues of the journal were pitched at too elementary a level to be of interest to most readers of this review, and they lack special merit, in general, even as elementary expositions. One in the November 1944 issue, unsigned, is particularly open to criticism. Dealing with the interesting problem of data showing highly skewed distributions in their original form, but approximating normality when transformed to logarithms, it suggests, reasonably

enough, the use of a chart for individual observations with an average at the geometric mean. It then determines "sigma" as one-third of the difference between the logarithm of the geometric mean and the logarithms of the extreme items in the distributions, and blandly accepts different values of "sigma" for positive and negative deviations. It misses the opportunity to advise plotting such data on paper with a logarithmic vertical scale. Evidencing a sense of the superiority of averages over individual observations for most control purposes, it remarks. "Perhaps readers of this article will elect to develop a solution of the problem of preparing control charts for averages and ranges of a nonsymmetrical distribution"—a suggestion that seems to reflect little understanding of the knowledge required for solution of the problem.

As a hasty improvisation under pressure of handling a plant problem, the method just summarized may be admired for its simplicity and ingenuity, but one may doubt whether similar problems were so prevalent and urgent that time could not well have been spared to develop a more efficient and rational solution before publishing on it. In any case, to allow "sigmas" obtained as just described to masquerade as standard deviations without apology is hardly excusable.

It was appropriate that discussions of statistical method in the early issues of *Industrial Quality Control* should be elementary, in keeping with the status of most of its subscribers as beginners in statistics. Later issues reflect recognition of substantial advance in the statistical competence of those whom the journal has undertaken to serve. The two latest issues (July and September 1945) contain useful short papers on "Use of Correlation in Quality Control" by Peter P. DiPaola and "Sequential Sampling Inspection for Attributes" by H. A. Freeman.

Worthy of special mention is a paper by Martin A. Brumbaugh in the September 1945 issue which presents a comparison of pre-war and present quality of the machine-shop work of one plant that adopted statistical control during the war. The paper takes advantage of an opportunity afforded by hasty storing of parts for a firm's pre-war product before screening inspection, when the plant was converted to war work. At the end of the war, when inspecting the stored parts, the chief inspector, who chooses to remain unidentified, seized the opportunity to make a record of the efficiency of pre-war control of quality. Professor Brumbaugh's comparison of the resulting data with similar information on current production shows strikingly that pre-war operations presented as much need for statistical control as was found in the production of war materials.

The Buffalo Society of Quality Control Engineers and the Editor of *Industrial Quality Control* are deserving of high praise for their publication. Its establishment and successful maintenance required imagination, initiative, and a great amount of hard work in the face of severe difficulties. Its editorial policy has shown a keen sense for the needs of its readers, and even its faults redound in considerable part to the credit of its sponsors, for they

must have known that the conditions of publication made defects inevitable, and have consciously braved criticism for the sake of rendering a service.

From the standpoint of service, one of the large contributions of *Industrial Quality Control* has been made through its pages of news and notes. Largely neglected in this review because of their generally ephemeral interest, these items have been a valued feature of the magazine, contributing substantially to advancement of the use of statistics in quality control through the encouragment that people get from knowing what others of like interests are doing.

Quality Control Reports, Nos. 1–12. Issued by the Quality Control Program, Carnegie Institute of Technology, for Office of Production Research and Development, War Production Board. *Holbrook Working* (Director, Quality Control Program; Professor of Prices and Statistics, Stanford University) and *Edwin G. Olds* (Associate Director, Quality Control Program; Associate Professor of Mathematics, Carnegie Institute of Technology) Washington: Office of Production Research and Development, Civilian Production Administration, 1945. Gratis. Paper.

No. 1, Introduction of Statistical Quality Control at Illinois Testing Laboratories, *James A. Fizzell* (Supervisor, Engineering Department, Illinois Testing Laboratories. Inc., Chicago). May 1945. Pp. 8.

No. 2, Organizations Concerned With Statistical Quality Control. *Holbrook Working* and *Edwin G. Olds*. June 1945. Pp. 38.

No. 3, Statistical Quality Control at the St. Louis Division of American Stove Company. *Lester A. Kauffman* (Director of Quality Control, American Stove Co., St. Louis, Mo.) August 1945. Pp. 22.

No. 4, Quality Control at the Lukas-Harold Corporation. *Carl G. Schmid* (Manager, Quality Control Department, Lukas-Harold Corp., Indianapolis, Ind.). August 1945. Pp. 10.

No. 5, Statistical Quality Control in Radio Manufacture. *Fred Trowbridge* (Quality Control Engineer) and *John T Clark* (Production Control Engineer). (Sentinel Radio Corp., Evanston, Ill.). September 1945. Pp. 12.

No. 6, An Application of Statistical Quality Control at the Hoover Ball and Bearing Company. *Russell C. Trombly* (Supervisor, Quality Control Department, Hoover Ball and Bearing Co., Ann Arbor, Mich). September 1945. Pp. 9.

No. 7, An Adaptation of Statistical Quality Control at Aldens'. *James M. Ballowe* (Manager, Inspections Department, Aldens' Chicago Mail Order Co., Chicago, Ill.). September 1945. Pp. 12.

No. 8, An Application of Statistical Quality Control at the John Deere Tractor Company. *E. L. Fay* (Chief Inspector, John Deere Tractor Co., Waterloo, Iowa). September 1945. Pp. 9.

No. 9, Statistical Quality Control at Lockheed. *James R. Crawford* (Manager, Manufacturing Reports Department, Lockheed Aircraft Corp., Burbank, Calif.) and *Preston C. Hammer* (Partner, Probity Engineers, Los Angeles, Calif.). September 1945. Pp. 17.

No. 10, Some Aspects of Statistical Quality Control in the Steel Industry. *Richard H. Ede* (Carnegie Illinois Steel Corp., Gary, Ind.) and *Earl W. Mahaney* (Metallurgist, Youngstown Sheet and Tube Co., Youngstown, Ohio). September 1945. Pp. 12.

No. 11, Bibliography on Statistical Quality Control. *Dorothy W. Goodfellow* (Editorial Assistant, OPRD Quality Control Program, Carnegie Institute of Technology). September 1945 Pp. 48.

No. 12, Some Experiments Illustrating Principles of Quality Control. *Irving W. Burr* (Associate Professor of Mathematics, Purdue University). September 1945. Pp. 12.

Two reviews follow:

REVIEW BY GEORGE W. BROWN
Research Engineer, R.C.A. Laboratories, Princeton, N. J.

THE 12 Quality Control Reports together constitute a testimonial to the success of the OPRD Quality Control Program in stimulating interest in statistical quality control in war industries and in guiding the organization of industrial quality control programs. The degree to which the subscribers to the OPRD Program have been repaid for their interest is really impressive, if these reports represent an approximately fair sample of the general experience of the organizations which availed themselves of the opportunities offered.

Nine of the reports describe individual quality control applications presented by quality control, inspection, and engineering executives covering a wide range in previous quality control experience, statistical training, and special fields, with the result that the reports themselves touch a correspondingly large variety of points of interest, including problems of organization, methods of introducing quality control techniques for the first time, and details of actual applications.

With respect to technical statistical details, there is little that need be said about these reports. With a few exceptions, they present standard control chart techniques applied to incoming material, process control, and final inspection. The greatest single gain, in the majority of cases presented, results, in the reviewer's opinion, from the combination of increased emphasis on quality at all levels with the continuous picture of the situation afforded by the control charts, providing a graphic goal of great psychological importance along with an intelligible description of the history of the process. Other gains which follow are more or less of the nature of improved inspection efficiency associated with sensible measurement and sampling, or of specification revision, made possible by knowledge of the statistical behavior of the process when in control.

The problem of whipping an out-of-control process into control is, of course, not subject to the routinization that is possible at the other control stages, nevertheless the obvious question which arises is to what extent can the quality control engineers take advantage of the well-known techniques in experimental design and analysis to shorten the time required to get a process under control for the first time. For example, it is not difficult to imagine short experiments which, without serious interference with production, would provide estimates of the variability associated with machines, operators, lots, etc., thereby facilitating the search for the "assignable causes" whose presence has been made known by the control chart. On the surface, at least, it appears likely that several of the authors might be ready to extend their services still more by the addition of analysis of variance techniques to their tools. The control chart itself is, after all, neither more nor less than an approximate analysis of variance in a particularly simple form.

Report No. 1 is of particular interest in that it describes the quality control experience of a small concern, employing fewer than 250 persons. In spite of the small size of the organization, statistical quality control was applied successfully both to incoming and plant inspection. In contrast, No. 9 deals with quality control on a gigantic scale, with statistical control being applied even to the number of parts inspected. No. 9 contains a description of a system of quality stamps for large scale operations; also of interest is a special statistical study involving inner diameters measured at four separate places in a single part.

For a detailed description of the process of locating and eliminating an assignable cause of variability, No. 5 is one of the better reports. There is also a nice example of a non-normal distribution, the distribution of the values of resistors purchased to a given tolerance, the non-normality resulting from the manufacturers' screening of resistors meeting a closer tolerance for other orders requiring the closer tolerance. The authors' example of humidity affecting the quality of the product raises the question whether the equipment in question was meant to operate satisfactorily under humid conditions. If so, a change in design should have been necessary; if not, the procedure adopted was satisfactory. This report also mentions the use of correlation methods and "t" tests in special studies.

No. 7 is unusual in that it concerns human efficiency alone, in a mail-order operation. It offers an excellent example of the effects of exhibiting a goal and keeping orderly data in a convenient form, as applied to order checking and office clerical work, where the problem is confined to one of management and employee efficiency, without the usual tool wear and material variability.

Part I of No. 10 is concerned primarily with correlation methods, rather than control chart applications, in preliminary analyses. It is interesting to note the author's stated intention of exploring the analysis of variance and experimental design techniques for controlled experiments. Part II is a detailed exposition (not entirely clear) of the process of setting up a sampling acceptance plan for process control at an intermediate stage, designed to reduce the amount of conditioning required on semifinished steel bars.

Nos. 3, 5, 6, and 8 are essentially conventional control chart applications, although No. 4 does contain a few very mild departures from "orthodox" American Standards Association procedures. No. 3 contains a very intelligent discussion about setting the mean well enough to stay within tolerances, given the variability, and on required variability limits for a given tolerance. No. 6 contains a control chart example where measurements seem to have been made to .001 when the tolerance was .002, the coarse measurement resulting in a very queer-looking chart. No. 8 has a good discussion of the problem of selling quality control to the organization and initiating the program. The highway analog is a rather amusing one, comparing the paved portion of a highway with the part between control limits, the shoul-

ders to the part between the control limits and the specification limits, and the ditches to the part outside the specification limits.

No. 2 is effectively a history of the OPRD Program, listing courses given, and the organizations and individuals connected with the various courses. The list of 810 organizations participating is certainly an impressive one, to this reviewer at least. This report, and the bibliography (No. 11), together make a useful supplement to any quality control library.

No. 12 exhibits some typical dice experiments which illustrate various quality control principles. Some of these experiments might well be listed as "musts" for individuals approaching quality control for the first time, to assist in acquiring a first hand feeling for the essential features of statistical variation. It is pointed out that p's of 1/6, or 1/3, say, obtainable with a single throw of a die, are too high to illustrate practical fraction-defective situations; the author then suggests using dice with more than six sides, or that have been "prepared." It is difficult to see why the author neglected the possibility of compounding probabilities with pairs, or greater numbers of throws, to get p's as low as desired. For example, with two throws, the probability of getting two aces is 1/36, the probability of getting an ace and a two is 1/18, the probability that the sum is at most three is 1/12, etc. It might also be pointed out that random number tables, such as may be found in Fisher and Yates, permit drawing samples from any preassigned statistical distribution, although for some purposes the effect may not be quite as satisfying as the equivalent dice experiment.

Review by Louis C. Young
Quality Control Supervisor, Westinghouse Electric Corporation
Springfield, Massachusetts

Report No. 1 describes the quality control operations carried out in a small plant under war time conditions with attention centered chiefly upon screw machine operation. By means of control charts, Mr. Fizzell found that the lack of adequate maintenance was the chief drawback to combined production and quality; the charts themselves proved the means of convincing management that steps needed be taken in this direction. Examples of the application of statistical methods to problems of incoming inspection and final inspection are also given in brief, but with no tangible evidence of increased economy of operation. It is interesting to note, in the problems and their solutions, that engineering and inspection functions are as often at fault as production.

No. 2 contains summary lists of attendance at the ESMWT courses conducted by the OPRD Quality Control Program, through May, 1945. Listed in separate tabulations are: business organizations represented in attendance; the educational institutions represented in attendance; the locations at which the courses were presented, with the dates of the first and subsequent presentations; instructors in the courses; special lecturers; and a list

of the several quality control societies formed as a result of the courses presented.

Concerned with the control methods used in a medium sized plant during war time, No. 3 considers control of both variate characteristics and attributes. The description of the former is made somewhat confusing by reference to a chart with incorrectly calculated limits. A greater part of the report stresses control by attributes, both in machining threads and in assembly welding, with detailed accounts of the troubles encountered and the process changes found necessary.

Dealing with the control of machining of parts for a very precise war instrument, where production and quality evidently far outweighed expense, No. 4 centers upon a portion of the machining operations and explains the organizational steps found necessary to expedite the control program. Emphasis is placed, due to the precision of the work, upon control by variables; this is particularly of interest because of the small volume of production turned out on each order—a source of complaint for many industrial concerns attempting the use of statistical methods to control quality. Reference to charts is made slightly difficult by misplacement of the numbers of the figures.

No. 5 begins with a general discussion of experience with statistical applications, and includes a few detailed comments on their applicability where test error is high. A specific example follows, well worth reading, of an operation which was uncontrolled (from a statistical viewpoint) and in which the controlled variation would have exceeded the tolerance. Solution of this problem involved tracking down certain specified causes of extreme variation, and in the use of modified control limits along the line of variate-consumer-risk thinking which has become widespread in Great Britain during the war years.

Limiting his report (No. 6) to a single dimension commonly giving trouble in the manufacture of ball bearings, Mr. Trombly describes his attempts to increase the degree of control over the form grinding of races, by means of variate control charts. In this case, the charts were also used subsequently as a form of acceptance inspection in order to reduce the amount of detail inspection given ball races; lots characterized by samples outside the control limits were sent to the inspection crib for detailing.

No. 7 describes the reduction of errors made in filling customer's orders, in a mail order house, by means of departmental charts showing daily ratios of errors to orders filled. Although the author occasionally interjects a note on the similarity of this application to those of manufacturing, the improvements shown and the manner in which cooperation was enlisted by display of charts leads to the belief that employee cooperation or conscience may be better in merchandising than it is in industry. The description of the simplicity and directness of charting an error ratio, regardless of the cause or type of error, will appeal to those who have become lost in the multinominal

forest while trying to account separately for a variety of quality characteristics.

The two examples of improvement in quality which are described in No. 8, dealing with the control of machining processes in a tractor factory, represent appropriate applications of the methods of variables and attributes: the former, in the treatment of readily measurable expensive piston pins; the latter, in reducing rejects of threaded nuts made on automatic screw machines. Although the latter operation is one which is commonly encountered in industrial statistical literature, the account is notably straight forward, practical, and interesting in its detail with regard to sampling procedure.

No. 9, a report of statistical application in an aviation plant, is noteworthy in two respects: the wartime requirement that the quality of many key parts be assured is more applicable to post-war production in aircraft assembly plants than in many other war plants; and the principal example of statistical solution of a manufacturing problem is one in which the solution rests upon the statistical manipulat on rather than upon customary common-sense consideration of inspection data,—a distinction which is less pronounced or lacking in the majority of current expositions on this subject. The use of a "quality audit" form in reporting departmental levels of quality and improvement, comparable to an expense and budget statement, serves to relate the technical and managerial phases of quality control in a practical and convincing manner.

No. 10, composed of two parts,—one dealing with the open hearth and pouring variables of molten steel; the other, with the rolling and skin conditions of steel blooms and billets in process,—is a study in the industrial application of correlation methods. In the first part, Mr. Ede describes several problems in steel manufacture, most of them concerned with the effect of chemical process factors upon the quality of steel in process, and explains the method by which each was solved and an improvement made in the process. Omission of the details on the trials and technical thought underlying the selection of method increases the clarity and brevity of this section, but detracts from an appreciation of the complexity of the problems. In the second part, Mr. Mahaney starts with the surface characteristics of steel in process and considers them as causative factors in the determination of final quality. A reduction in process time and expense is demonstrated by means of a sampling plan centering upon attribute inspection of work in process.

No. 11 is a bibliography divided into three sections, of which the first is devoted to articles on industrial statistics and quality control. This section is the most complete listing seen by the reviewer, and is laudable for the saving in time and effort it will afford those seeking information and examples of statistical control in specific industrial fields. The second section lists a number of technical publications issued by industrial firms and insti-

tutions, including those of the American Standards Association, the Bell System, the OPRD reports, and others. The third section lists books "suggested by men in various areas of statistical quality control as having been useful to them."

No. 12 describes some experiments with dice, paralleling the control chart accumulation and judgment of data. In this capacity, the report bridges the gap necessarily left in the American Standards Association war standards on quality control; by using a background of purely chance causes, the author delivers that conception of control needed by any novice in industrial statistics. At one point, Mr. Burr discusses the errors made possible by stratified sampling as opposed to rational sampling, and demonstrates by rearranging the same data into both types of sample. Although the error (of overestimating variance) is real, it is implicitly blamed upon the method of sampling, whereas it might be stated more validly as an error in the statistical treatment of data. The report also surveys, by means of similar experiments with dice, the field of acceptance sampling. The constant system of causes is used to show that an occasional sample may be so good as to justify reduced inspection, but that subsequent samples inspected under these conditions will soon cause reversion to increased inspection for the specific sampling plan and process average under consideration.

Symposium of Papers on Statistical Quality Control. Birmingham 3, England: Quality Control Panel, Birmingham District Production Committee, Ministry of Production (C.M.L. Building, Great Charles St.), [March 1945]. Pp. 76. Gratis. Paper.

Introduction, Quality Control in Industry, pp. 2–4. *W. A. Bennett* (Works Manager, English Needle and Fishing Tackle Co., Ltd., Studley, Warwickshire, England).

Lecture 1, Direct Measurement, pp. 5–8. *E. H. Sealy* (Management Consultant, Orwick, Orr and Partners Ltd., 7 Park Lane, London, W.1.).

Lecture 2, Number Defectives, pp. 9–21. *D. J. Desmond* (Research Chemist, Joseph Lucas Ltd., Great King St., Birmingham, England).

Lecture 3, Application and Organisation of Statistical Quality Control in a Light Engineering Plant, pp. 22–37 *D. S. Mc Naughton* (Chief Inspector, Hercules Cycle and Motor Co., Minor Works, Birmingham 6, England).

Lecture 4, Part 1. Practical Application of Statistical Quality Control in the Press Shop, pp. 38–39. *W. N. Baker* (Technical Assistant, I.C.I. Metals, Ltd., Witton, Birmingham, England).

Lecture 4, Part 2. The Practical Application and Organisation of Statistical Quality Control in Deep Drawing Press Shop, pp. 40–44. *H. C. Webb* (Chief Inspector, I.C.I. Metals, Ltd.).

Lecture 5, Sampling Schemes for Number Defectives Inspection, for Quality Estimation of Single Lots, pp. 45–66. *A. W. Swan* (The United Steel Companies Ltd., 17 Westbourne Road, Sheffield 10, England).

Lecture 6, Associated Statistical Techniques, pp. 67–74 *J. W. Rodgers* (Chief Metallurgist, English Needle and Tackle Co. Ltd.). ***Two reviews follow:***

REVIEW BY IRVING W. BURR
Associate Professor of Mathematics, Purdue University

THIS book is a collection of papers discussing the application of statistical methods of quality control to industrial problems. The opening paper is a

good general introduction to the problems of where and how to use the methods in a plant. Mr. Sealy's paper explains clearly the basis of measurement control charts and the relationship of control limits and specifications, bringing in modified control limits. Mr. Desmond gives the typical application of fraction defective and then discusses the advantages of using a compressed or narrow tolerance and studying by chart the number of cases outside these limits. In this way there are enough "rejects" to enable the use of small samples. Both papers are well illustrated with diagrams and shop problems. Neither paper would be quite complete for the beginner, but both contain useful material.

The three application papers are excellent for presenting the kinds of problems which are met in practice, their solution and the general economic value of control chart methods. An industrial man will find many useful tips and adaptations, such as, a sampling compromise (last two pieces from the machine and three at random from the tote box) and the group control chart for automatics (McNaughton), the extent of applications (Baker), and the economic decision of when and when not to use the methods (Webb).

Mr. Swan's paper discusses the problem of designing single and double sampling inspection plans for attributes. The aim would seem to be to help one design his own sampling plan. The general outline for single sampling is (*a*) to choose the maximum number of pieces which can be called a lot, (*b*) to decide what is the maximum percentage of a lot which one can afford to inspect, (*c*) to determine the process average and decide upon the producer's risk at this level, and (*d*) to decide what consumer's risk to assume for some to-be-determined lot tolerance fraction. There will then be several choices of pairs of sample size and lot tolerance quality. The practical choice can be made to minimize the former or to use the lowest value of the latter. This is an interesting approach and may well be that desired by some operators. The paper is not, however, very clearly written and in particular it is difficult to find out what mathematical methods were used in the derivations. For example, the Poisson, binomial or hypergeometric distributions are not always indicated, the basis of Table IV is not presented, nor are there adequate references. On page 50 after Table III, there seems no particular reason why a sample for 105 and lot tolerance of 5 per cent would not better meet the author's desires.

Mr. Swan's double sampling plan involves two equal samples making up the equivalent of a single sample. This may or may not be an economical set-up. The section "Operating a Double Sampling System" contains two serious defects. The Operating Characteristic of a process is "the way in which the quality swings up and down about an average percentage of defectives." The point is that even when the quality level is stable at say 1 per cent defective, the fraction defective of lots actually sent will vary around this level in a random and well understood manner. Knowing the probability of acceptance of a lot of any given fraction and the probability of occur-

rence of such a level, then one can by using the latter as weights find an average outgoing quality for the manufacturing stream which is under control at 1 per cent. Average amount of sampling inspection is similarly available. Mr. Swan errs, however, in using as weights, not the probability of such lot quality levels, but the probability of such sample levels. Hence his averaged results are meaningless.

The second point is that it is actually unnecessary to use the weighting of probability of occurrence of each lot level, because if the process level is at 1 per cent this gives a constant probability of occurrence of a "pass" sample and of a "reject" sample a priori. The sampled part of the lot is not correlated *at all* with the remainder of the lot (if the process is stable at 1 per cent). It is as though we were to take a sample of 150 consecutive pieces from the process, make our decision to pass or reject and then to choose 850 more to complete the lot. The quality in the remainder will average 1 per cent in the long run regardless of what has happened in the first 150. Looked at this way it is a most simple matter to calculate the average outgoing quality. The method using lot quality weights looks convincing, sensible and correct, because it is. But so is the above simpler method. The two give the same results because both are correct.

Mr. Swan's paper has many interesting points for one familiar with say the Dodge and Romig tables (reviewed in this JOURNAL 40 (231): 382–384 S '45). It is scarcely safe nor clear reading, however, for one relatively unfamiliar with sampling inspection by attributes.

Mr. Rodgers primarily discusses two topics: tests of normality and analysis of variance. Neither topic is discussed fully enough to be very helpful to the practical man. Ranges are used for the analysis of variance, which is useful. It is not possible to check upon the accuracy of the suggested methods since the interpretations, tests and applications to be made are not indicated.

The book as a whole has much of interest to well repay careful reading.

REVIEW BY PAUL PEACH
Industrial Statistician, Institute of Statistics
University of North Carolina, Raleigh

DURING the war both British and American war agencies found it worth while to promote the use of statistics in industry. In the United States the War Production Board and the Office of Education organized short training courses in statistical quality control; there was very little supervision of actual factory installations. In England the Ministry of Production and the Ministry of Supply gathered together a number of qualified persons and set up consulting groups, or panels, whose services were made available to industry and who, it appears, worked very close to the production line. As part of their educational program they presented lectures on industrial applications of statistics. This booklet gives six lectures of a series of eight presented in Birmingham in June-July, 1944.

The content of each lecture is indicated by its title. As might have been expected, the treatment is somewhat uneven. The third and fourth lectures are severely practical; the other four are more theoretical, though not objectionably so. The lectures must have been effective and successful, but in printed form they will, in this reviewer's opinion, be interesting chiefly as history, not as reference or teaching material.

For illustration, consider the last sentence of Lecture 1, by Mr. Sealy, on control charts for measurements: "The lecture was then illustrated by several examples of charts taken from actual factory practice." The presentation and discussion of these charts must have been one of the highlights of the meeting; but nothing more appears in the printed version. Here is an extreme instance of the difference between writing for readers and writing for hearers. The speaker uses not merely words, but inflections, gesture, emphasis; he probably has a blackboard handy; he senses his audience reaction and modifies his presentation accordingly. The stenographic report of a lecture, whipped into shape for publication, often appears tremendously overcondensed, simply because so much of the ancillary nonverbal exposition is lost.

The present pamphlet suffers from this defect. A second objectionable feature has to do with the figures. Save for those of Webb and Baker, each lecture is illustrated with figures and charts. In Sealy's lecture the figures are dispersed through the text, but for the rest all figures are collected in a sort of appendix to the lecture; this makes for awkward reading. The awkwardness is increased for American readers by the use of w instead of R for range; the references, too, are chiefly to British sources.

The lectures by Sealy and Desmond present familiar elementary principles; those by McNaughton, Webb, and Baker are practical talks which must have been very effective when delivered and retain much of their effectiveness in print. The sixth lecture, by Rodgers, mentions briefly a few more advanced statistical techniques such as the chi-square test and the analysis of variance.

Lecture 5, by A. W. Swan, was of particular interest to this reviewer. It is a discussion of acceptance sampling for lot-by-lot inspection. Swan gives credit to Capt. A. H. R. Grimsey, Military College of Science, in connection with the single and double sampling plans here presented. These plans are based on the ratio "Maximum Allowable/Process Average," as are the Dodge-Romig tables of 1929 and a table recently devised by the writer and a colleague; the Swan-Grimsey single sample tables are not especially compact, and overlook the simplification that can be obtained by using chi-square. Swan and Grimsey also propose the use of two equal samples for double sampling, thus again anticipating this reviewer. The Swan-Grimsey double sampling plans are arrived at by trial and error, with considerable computation. No adequate tables are given. However effective the spoken lecture may have been, the written presentation is difficult to follow.

During the war the need was for quick results at any cost. There was no time

to give really fundamental instruction in industrial and engineering statistics. The highly condensed material and intensive instruction of war days will no doubt give place to the slower, more orderly and more thorough training of engineers and others in statistical science as part of their college education. The lectures of the present pamphlet served a purpose, and an important one; but the pamphlet itself, in the reviewer's opinion, will have little utility in the postwar period.

Industrial Experimentation. *K. A. Brownlee* (Directorate of Ordnance Factories, Explosives, London). Memorandum No. 18. London, W.C.2: S.N. 7 Branch, Directorate of Royal Ordnance Factories (Explosives), Ministry of Supply, [The Adelphi], 1945. Pp. 87. Paper. *Two reviews follow:*

REVIEW BY JOHN W. TUKEY
Assistant Professor of Mathematics, Princeton University

THE PURPOSE, scope, and origin of this pamphlet are clearly expressed in the Foreword (italics ours):

> The present memorandum has grown out of an appreciation of the desirability of subjecting experimental results to a critical statistical test of significance. It was evident that a convenient account of the straightforward tests of significance, written from the point of view of the individual who has to apply them in practice *without* necessarily *a full knowledge of their* theoretical *background*, was not readily available, and an attempt was therefore made to prepare one. As this work proceeded it became evident that, to apply tests of significance economically, the experiments had to be planned in appropriate forms. In its present form, therefore, the Memorandum is intended to be a guide to the planning and interpretation of experiments on the industrial scale, and it is hoped that its contents will become part of the everyday technique of those who carry out such experiments.

The author has carried out this task with clarity and precision, using chemical engineering examples. The pamphlet can be highly recommended to all interested in industrial experiment as a satisfactory manual of Fisherian statistics. It covers the significance of means, the comparison of variances, the χ^2 test, the analysis of variance, correlation, regression, and factorial experiment. It should prove particularly interesting, of course, to those interested in chemical engineering problems, but workers in other fields will find transfer a simple problem.

This is a brief manual for those without a full knowledge of the background of the tests—in short, a cookbook. It is a very good cookbook, whose recipes have been developed in agriculture and well tested in many other fields, but it is not, and could not be in so short a space, a treatise on the physical chemistry of cooking. The average cooking problem can be solved with a cookbook—very many industrial problems can be satisfactorily solved by mechanical use of these well-tested statistical procedures.

The distinction between statistical significance and practical significance is nowhere made clearly and precisely. The manner in which confidence inter-

vals are used in some discussions indicates the author's appreciation of this difference, yet there is no discussion of what to do if an immediate decision must be based on statistically insufficient data. There appears to be an undue tendency to believe all effects zero until statistically proved otherwise and to leave no place for parallel experience.

The brief discussion of control chart procedures gives little guidance in choosing between control chart and Fisherian methods in a specific instance, yet many of the examples which the author treats simply and directly would be difficult or impossible to treat by control chart methods. The control chart procedure was designed and is fitted to study processes which are or should be in control—that is, the successive values resemble a random sample. The Fisherian methods were designed and are fitted to study processes which are not in control, but where auxiliary data or the recurrence of the uncontrolled effects allows the partial separation of different effects. This distinction is fundamental.

In general, the possible use of methods based on order statistics is given insufficient consideration. In particular, the "maximum efficiency" of the variance is stated without restriction on page 9.

This is, of course, related to the general tendency to assume normality. Many small errors operating independently are said to produce normality—no mention that the effects must behave additively. The general principle is enunciated (p. 11) that departure from normality must be "very severe" before significance tests become appreciately inaccurate. This is not the case for Bartlett's test for the homogeneity of variances, which is described on page 18. The examples of pot life on pages 14, 28, and 31 do not seem to represent even nearly normal distributions. This is not surprising, since life is rarely normally distributed.

In carrying out the analysis of variance, the procedure used is to test doubtfully significant mean squares and, if they are not significant at the 5 per cent point, to then pool them into a new estimate of error mean square. The possible pitfalls in this process require much careful consideration. The estimation of contributions of different sources to variance is done in a similar way, making the flat assumption that each σ^2 is either actually zero or statistically significantly different from zero.

By requiring a minimum cell frequency of 5, the author restricts the usefulness of χ^2 to what now seems to be an excessive extent.

In discussing variance on page 25, the author states unreservedly that, if several factors contribute to a variance, then that variance is the sum of the component variances. This statement tacitly assumes that the factors are independent and that they act additively.

In discussing the two regression lines on page 43, the author states that he is concerned with predictive relations and not with structural relations. The reviewer cannot accept this as a general principle and feels that there are many problems of chemical engineering where the structural regression is important.

On page 34, the author assigns a certain component of variance to "bagging the material." While this is possible, it seems more likely to be associated with the process of taking samples.

This pamphlet has now been criticized on several lines. But—the reviewer knows of no book to which the reader may go for a better treatment of these critical points. The faults are those of the current statistical literature, not of this pamphlet alone.

On page 17, the author makes his only direct slip. He uses a two-tailed F test in comparing two variances without stating that the 5 per cent level has now become the 10 per cent level, and so on.

REVIEW BY J. WOLFOWITZ
Institute of Statistics, University of North Carolina, Raleigh

THIS short book is intended as a description of the more important statistical methods suitable for use in chemical manufacture and is written "from the point of view of the individual who has to apply them in practice without necessarily a full knowledge of their theoretical background." Within the compass of eighty-seven pages it discusses a wide range of topics. After several introductory pages designed to explain statistical fundamentals comes a chapter devoted to the t-test. A brief chapter discusses estimation of the variance, both by point and interval. Chapters on the chi-square test, the analysis of variance, regression, correlation, and factorial design contain the classical material to be expected in such a brief treatment. Two pages are given to a discussion of the quality control chart for ranges and means; in the latter the control lines are located by using the estimate of the range. Four tables are reproduced from Fisher and Yates and one for control charts is reprinted from Dudding and Jennett's British Standard.

As another statistics book written as a manual the present one contains a number of examples drawn from the chemical industry, and is a handy compendium of a number of computational procedures. The author is obviously enthusiastic about the applicability of statistical procedures to the chemical industry and anxious to encourage their use.

A question that merits raising is whether this type of book ought not to be written somewhat differently. This reviewer would prefer to see more emphasis on fundamental ideas. The assumptions underlying each technique should be clearly expressed and carefully described. While the mathematical argument which leads from assumptions to conclusions should be omitted in a book written for the sort of public for which the present book is intended, it is still possible in most cases to explain the fundamental assumptions to the intelligent layman without recourse to any complex mathematical ideas. If space is lacking, it seems desirable to this reviewer to obtain it by reducing or eliminating the considerable detail in which computational techniques are usually described, since misapplication of statistical methods is more likely to be serious than the use of inefficient computing techniques. Much circumlocution could be avoided and considerable clarity and precision

gained if formulae were stated in algebraic symbols, and not described in words and computational procedures designed to be imitated. Omission of mathematics implies to the reviewer's mind the omission of mathematical ideas or arguments of any complexity; the knowledge required to read the elementary algebraic symbolism in which the classical statistical formulae are expressed is now taught at a comparatively early age and is a part of the knowledge of a large section of the population.

The present book contains a number of errors, which are the more serious in that the book is intended for a type of reader who lacks the technical training to be competently critical. A few examples follow:

a) No distinction is made between the population variance and its sample estimate, either in symbolism or in the text (*vide* bottom of page 12).

b) The author fails to realize that a population parameter being estimated is not a chance variable. This occurs in a number of places; for example, on page 14 the author states " . . . the mean has a 95% chance of lying anywhere between 0.18 and −2.38," where the mean referred to is the population mean.

c) The author defines the variance ratio F as the ratio of the larger variance to the smaller. The effect of this is to double the intended size of the critical region under the null hypothesis.

The present book is prefaced by a short introduction written by an official of the British Ministry of Supply, and it is only through his brief acknowledgment that we learn the name of the author. The proper allocation of scientific credit is important not only as a matter of justice, but also because, in the present atomic era, it seems likely that more and more research will be done in large organizations and by scientific teams, and only proper allocation of credit will bring true merit to the fore. A book should bear the name of its author and not that of any administrative bigwig who is his senior in some organizational hierarchy.

On Statistical Treatment of the Results of Parallel Trials With Special Reference to Fishery Research. *H. J. Buchanan-Wollaston* (Principal Naturalist on the staff of the Ministry of Agriculture and Fisheries, working at the Laboratories of the Freshwater Biological Association, Wray Castle, Ambleside, Westmorland, England). Ambleside, Westmorland, England: Freshwater Biological Association of the British Empire, Wray Castle, 1945. Pp. 55. 2*s*. 8*d*. Paper. *Two reviews follow:*

REVIEW BY A. M. MOOD
Statistical Laboratory, Iowa State College

FISHERY research enters only incidentally (in some of the illustrative examples) in this booklet which is primarily concerned with tests of significance for 2×2 tables and for samples from binomial populations. The author addresses himself to people with little or no knowledge of statistics, it being his aim to encourage greater use of statistical techniques by workers in fishery research. While such missionary efforts deserve the highest praise,

especially in this case because the author's methodology is excellent, the beginner is warned not to read this booklet for his introduction to statistics. The sentences are complex; the ideas are expressed in very general language; and many technical terms of statistics are used without explanation or definition.

For statisticians, the booklet may be described as an elaboration of Fisher's treatment of 2×2 tables and binomial populations in his *Statistical Methods for Research Workers*. Exact and approximate methods for computing probability levels are fully discussed and illustrated. The author urges research workers to report exact probability levels rather than state merely that P is less than .01 or between .05 and .01 for example. To this end he does not hesitate to recommend quite burdensome arithmetical computations when there is no simpler method of obtaining the exact value. Most statisticians would be less insistent on this point.

A table is provided of the exact probability distributions for 2×2 tables in which one pair of marginal totals are equal. Distributions are given for $n = 2, 3, \cdots, 15, 20, 30$, where n is one of the two equal marginal totals. The table would be quite useful to research workers who commonly encounter data of this kind.

The author also presents an interesting technique for combining several experiments in one test of significance when the data are not sufficiently homogeneous that they can be combined directly. The method consists of finding the normal deviates corresponding to the probability levels of the separate experiments, then testing the hypothesis that the deviates are a random sample from a normal population with zero mean and unit variance. This method would be used when the deviates could be given meaningful signs, and would in this circumstance be preferable to Fisher's method of taking minus twice the logarithms of the probability levels to be chi squares with two degrees of freedom.

REVIEW BY MILNER B. SCHAEFER
Instructor in Fisheries, University of Washington

THIS booklet deals with enumeration data, arising from parallel trials, to which may be applied tests of significance based on the fourfold table or on the binomial distribution. Throughout, the result of two parallel trials is considered as the difference between the number of times a specified event has occurred in the two trials. Significance is judged by the probability of the occurrence under a null hypothesis of a difference at least as great as that observed. Procedures are given for computing this probability exactly for the fourfold table and for the binomial series. A table of logarithms of the binomial coefficients up to 50 terms is included and greatly facilitates the computations. For the case in which the number of individuals, n, is the same in the two trials, tables of the probability, $P(d)$, for all values of the difference are given for $n \leqq 15$, $n = 20$, $n = 30$. In addition to the exact methods, several methods of approxi-

mating to $P(d)$ are demonstrated for the fourfold table. A method of approximating to the sum of the terms of the binomial series above a given term is presented, based on summing a geometric series, the common ratio of which is estimated from successive terms of the binomial. The testing of the homogeneity of results from several sets of trials, and the combination of results from such trials when they are heterogeneous are briefly treated.

The material is presented almost in the form of a manual of procedures. Each "test" is presented in a separate section, and numerical examples are given in each case. Toward the end of the paper is included a section on "suggestions as to choice of method for testing for significance in particular cases," which will assist the user in selecting tests for his own data. A final section gives examples of problems to which the various methods may be applied. The theoretical basis of the paper is left to eight pages of "theoretical notes" near the end. This method of presentation will facilitate the use of the procedures by biologists and others wishing to employ the tests in the analysis of their own data. However, some unity of subject matter is thereby lost, and it could be wished that the interrelationships of the various sections had been more clearly indicated. For example, the method (of Yates) given in section 6 for computing $P(d)$ in cases where there are over 50 individuals in the trial may be equally well applied to cases with fewer individuals, and, indeed, the formula employed therein is the same as that of sections 1 and 2, but here the factorial products are evaluated by means of the table of binomial coefficients.

The null hypothesis as a basis for tests of significance is discussed in the introduction, and is again emphasized in connection with the various procedures. This, together with a separate section "on the philosophical basis of tests for significance," should give readers with a limited background of statistical theory a valuable insight into the logic underlying the methods of this paper.

The examples employed in illustrating the procedures are drawn from various problems arising in fisheries studies, but the methods will be found generally applicable in other fields.

Statistical Methods in Quality Control. *P. C. Clarke* and *G. R. Armstrong.* (Engineering Department, Hunter Pressed Steel Co.) Engineering Data Book Section 29. Lansdale, Pa.: Hunter Pressed Steel Co., 1945. Pp. 100 (pagination irregular).

REVIEW BY G. R. GAUSE
Bell Telephone Laboratories, Inc., New York, N. Y.

THIS book presents in looseleaf style a description of the quality control methods which have been found useful by the Hunter Pressed Steel Company. The pages are exact reproductions of data sheets which were prepared by the company for their inspectors and inspector trainees, being in large part specific operational procedures to be followed by the inspection per-

sonnel. As such, the book lacks some of the continuity which is desirable in a textbook. However, the simplicity of presentation and the wealth of practical illustrations should make the book of much value both to the young engineer who is starting out in quality control work and to the teacher of industrial statistics. To the young engineer, this book, supplemented by one of the standard texts, should be invaluable in bridging over the gap between the more abstract considerations and the practical applications. To the teacher, it provides both techniques for the presentation of some of the fundamental concepts of quality control and also many numerical examples of practical applications.

The first part deals with frequency distributions. The concept of a frequency distribution is very cleverly and lucidly developed through a series of simple examples and illustrations. Detailed procedures are given for calculating $\overline{X}$ and σ and for estimating fraction defective from computed values of $\overline{X}$ and σ. The method given for calculating $\overline{X}$ and σ from the observed fractions defective in two tails of a distribution is, as far as this reviewer's knowledge goes, here published the first time. The method should be of practical value in many instances. However, as the author undoubtedly realizes, the method given can be dangerous if not handled with caution. Had the book been prepared for the general public rather than for use by a particular company under careful supervision, it would have been desirable to include some cautioning remarks as to the dangers inherent in making predictions from such calculations, particularly when the observed fractions defective are both in the neighborhood of .50. The illustrations of the effect upon frequency distributions of such things as tool wear, heat treating operations, and other factors should be particularly helpful to the practical man who is trying to understand what frequency distributions have to do with making a satisfactory product.

The second portion of the book deals with correlation between two quality characteristics. The treatment omits completely all the mathematics of correlation and treats the subject in a simple graphical manner such as is so helpful to the shop man in quickly detecting pronounced relationships and in presenting these relationships in an obvious manner. Illustrations are given as to practical applications which resulted in the solution of quality problems in the shop.

The last portion of the book deals with control charts. In general, the methods presented are those of the American Standards Association with several additions which have been found useful by the authors. One of these additions is the use of "reject limits." The "reject limits" are placed inside the specification limits by a factor depending upon sample size and observed average range. Sample averages falling outside these "reject limits" are considered by the company as sufficient cause for stopping production and making adjustment. The limits are of the same nature as those described by E. H. Sealy in his book *A First Guide to Quality Control for Engineers*, in which book the limits are termed "modified control limits." It is interesting

to note that the Hunter Pressed Steel Company has found such limits to be of considerable value in their day-to-day work. Another addition is the "control gaging" technique. This is provided as a substitute for the routine keeping of control charts by variables and consists in setting go not-go gages at the control limits for averages of samples of five. The inspection procedure then consists in gaging with the "control gage" a sample of five pieces at periodic intervals. If more than two pieces fail either the go or the not-go gage, an adjustment of machinery is required. It is pointed out that this procedure eliminates the measuring of individual pieces, the calculation of averages and ranges, and the plotting of points, yet furnishes a practical means of control where more refined methods are not justified. It would be interesting to know if the company has tried setting the "control gages" inward from the specification limits by a factor of observed range rather than outward from the center of the specification tolerance range. Such a setting of the control gages would correspond to the "reject limits" which apparently have been found to be so successful and would automatically take care of situations such as that described on page 114 in which there is a relatively small range but a pronounced trend in averages. Another addition to techniques described in the ASA Standards is a procedure to be followed on short-run jobs which cannot be treated as a continuous production situation. The procedure given illustrates the fact that applications of quality control methods need not be confined to continuous mass production.

A number of reproductions of control charts prepared on the job are given at the end of the book.

The Recovery of Inter-Block Information in Quasi-Factorial Designs with Incomplete Data. Commonwealth of Australia, Council for Scientific and Industrial Research. *E. A. Cornish* (Officer-in-Charge, Section of Mathematical Statistics, the Council). East Melbourne, C. 2, Australia: the Council, 314 Albert St. Gratis. Paper.

1, Square, Triple, and Cubic Lattices. Bulletin No. 158. 1943. Pp. 22.

2, Lattice Squares. Bulletin 175. 1944. Pp. 19.

REVIEW BY C. H. GOULDEN
Officer-in-Charge, Dominion Laboratory of Cereal Breeding
Winnipeg, Manitoba, Canada

THESE papers are a continuation of a series in which the author presents correct methods of analysis for incomplete block or quasi-factorial experiments when the data are incomplete. In order to familiarize the reader with the terms and symbols used, the author presents first the fundamentals of the theory underlying each type of experiment with which he deals. The formulas for the estimation of missing values are then presented clearly and detailed instructions are given for the solution of the rather more perplexing problem of making adjustments to sums of squares for use in tests of significance. The methods described, together with those given in previous papers, bring up to date the methods of analysis for quasi-factorial designs for the three situations that arise in the use of experiments of this type,

(*a*) when there are no real differences between the blocks and consequently no adjustments are required, (*b*) when the differences between the blocks are very large and full adjustments are made, and (*c*) when the differences between the blocks are intermediate between the extremes as in (*a*) and (*b*) and the magnitude of the adjustments made are based on an estimate of the block differences determined from the data of the experiment. Actual examples are given.

Lectures on Probability and Statistics. *Edward L. Dodd* (Late Professor of Actuarial Mathematics, University of Texas). Austin, Texas: University of Texas Press, 1945. Pp. 44. Gratis. Paper.

REVIEW BY THOMAS N. E. GREVILLE
Actuarial Mathematician, Bureau of Census, Washington

THIS booklet contains three lectures given by the late Professor Dodd on the theory of means or averages, together with a biographical sketch of the author. The lectures do not pretend to cover the subject exhaustively, but are of a semi-popular nature, seeking to indicate the general nature of the subject and to stimulate interest. For those who desire to read further, references are given to all the important papers. Much of the discussion in the second and third lectures centers around certain highly generalized defitions of a mean or average, of which the familiar types, such as arithmetic, geometric, and harmonic means, median, mode, and midrange, are special cases. To the uninitiated this is likely to appear a highly academic study, but the author shows by several well chosen examples taken from the fields of statistics, compound interest, and actuarial science that a number of unusual or peculiar types of means or averages are in common use for certain purposes. In the third lecture, mention is made of a number of specific properties which have been used to classify the various types of means. For example, a mean of a set of numbers is said to be internal if it lies between the greatest and the smallest of the numbers, or at worst equals the maximum or minimum value; it is said to be associative if it remains unchanged when all the numbers in any subset (taken at pleasure) are replaced by the mean for that subset. In the opinion of the reviewer, these lectures admirably fulfil their purpose of popularizing and arousing interest in the subject.

An Introduction to Industrial Statistics and Quality Control. *Paul Peach* (Industrial Statistician, Institute of Statistics, University of North Carolina, Raleigh). Raleigh, N. C.: L. B. Phillips Company, 1945. Pp. ix, 150. Out of print. Paper. (Revised edition in press, Edwards & Broughton, Raleigh, N. C.)

REVIEW BY J. H. CURTISS
*Lt. Comdr., USNR, Bureau of Ships, Washington, D. C.**

THIS book is a preliminary edition, in mimeographed form, of a textbook on statistical quality control which Mr. Peach is now preparing. While the

* The opinions expressed in this article are those of the author and are not to be construed as reflecting the views of the Navy Department or the Naval Service at large.

number of copies obtainable is limited, the scarcity of satisfactory working texts in this field seems to justify paying especial attention to the present work.

The immediate background of the book was Mr. Peach's experience as a teacher in the eight-day quality control courses given during the war in various industrial centers by a unit of the WPB under Mr. Holbrook Working. The effect of these courses in spreading the word on statistical quality control has been extremely significant. Although this book goes considerably beyond the subject matter of the eight-day courses, and changes the order of presentation of topics usually employed in them, it is nevertheless a fairly obvious outgrowth of the schedule employed for the courses. It thus derives a certain importance from being the first formal write-up in book form of the subject matter of the WPB program.

This is not meant to impute any lack of originality to the author. As stated above, many topics are included which were not treated in the WPB courses, and some of the devices employed seem to have originated with the author.

The order of presentation departs somewhat from that of the WPB courses in that acceptance sampling is presented before control charts. From the theoretical viewpoint, this is certainly the way to go about the matter, but some teachers of quality control prefer to put the control charts first. The presentation of the rationale of acceptance sampling is very well done. A system for selecting single sampling plans by attributes on the basis of the ratio p_2/p_1 is given, which is essentially the same as that employed in the earlier paper by Dodge and Romig on acceptance sampling.* The reviewer would have supposed that it would have been advisable to defer the details of selecting sampling plans in this way to a later portion of the book, but a personal contact with a correspondence-school student who is using the text has revealed that he was not particularly discouraged by encountering such complications at an early stage in the work.

Acceptance sampling by attributes leads naturally to the p-chart, although the distinction is not carefully made between the control of quality of the process and of the individual lot. The $\bar{x}$ and R chart appears next, after some discussion of the standard deviation. A novelty then appears in the form of a quality control method for short runs. It essentially involves the use of the sample mean and standard deviation to control the proportion defective, assuming a normal distribution. It might be advisable to use the non-central t distribution for this purpose; perhaps this modification will appear in the final edition.

At this point in the book, a certain evidence of haste seems to make its appearance in the organization of material. The list of contents from here on in reads as follows: The Chart for c; Multiple Sampling; AOQL Inspection; Acceptance Inspection by Variables; Specifications and Tolerances; Trend Control; Gages, Sampling, and Scientific Measurements; An Introduction

* H. F. Dodge and H. G. Romig, "A Method of Sampling Inspection," *Bell System Technical Journal*, 8:613–31 O '29.

to the Analysis of Variance; General Remarks on Raw Materials Acceptance; Organizing the Quality Control Department. Each topic receives a good, although brief treatment, but the net effect is a little bewildering. Undoubtedly the problem of organization and emphasis will be solved more satisfactorily in the final edition.

There are very few really misleading statements. Perhaps the reviewer's chief criticism would be that no connection is established between the *a priori* definition of probability used to introduce the topic and the frequency ratio definition which underlies much of the applications. A few statements need a little qualification: on page 9 it is stated without mention of independence that the variance of a sum is equal to the sum of the variances; on page 18 it is alleged that it is impossible to gage the quality of a lot by a sample (which denies the theory of statistical estimation); and on page 75 it is observed that the theory of double sampling is incomplete and existing tables are empirical, which is perhaps a little misleading.

These minor blemishes do not really mar a very accurate and readable book. Indeed, this work is exceptionally well written from start to finish. It is one of the best elementary expositions of statistical methods which the reviewer has ever encountered. The author is apparently a very fine teacher in his chosen field. He shows a grasp of the theoretical background which is particularly commendable in view of the fact that much of the attention in the exposition is necessarily centered on keeping the text strictly down to earth.

The Analysis of Cubic Lattice Designs in Varietal Trials. *I. F. Phipps, A. T. Pugsley, S. R. Hockley,* (Waite Agricultural Research Institute, University of Adelaide, Adelaide, South Australia); *E. A. Cornish* (Officer-in-Charge, Section of Mathematical Statistics, Council for Scientific and Industrial Research). Commonwealth of Australia, Council for Scientific and Industrial Research, Bulletin No. 176. East Melbourne, Australia: Council for Scientific and Industrial Research, 314 Albert St., 1944. Pp. 41. Gratis. Paper.

REVIEWED BY GERTRUDE M. COX
Director, Institute of Statistics
University of North Carolina, Raleigh

THE authors present the construction of the unbalanced cubic lattice designs and discuss their value in favorable terms. Their own summary is concise and to the point: "The paper describes in detail the procedure to be adopted for recovering inter-block information in cubic lattice designs, and the computations which are required for this full analysis are illustrated by a numerical example."

This bulletin follows closely Yate's original description illustrating the recovery of inter-block information in cubic lattice designs published in 1939. The authors are correct in their statement that reprints of Yate's article are not readily available. A volume of the *Annals of Eugenics* cannot be used extensively by computers in a laboratory. Therefore, a bulletin such as this one provides a useful guide.

The formulae in both articles are the same but the notation differs in minor details. To solve block components (a), (b), and (c) a series of separate tables 2, 3, 4 and 5 are constructed. This makes the computing instructions much easier to follow than those given by Yates.

After giving the logic of the computing involved to secure component (c), the contribution from tables 3a, 3b and 3c could all be thrown into one solution, thus making the process straight forward for computers.

The conditions specified for using these block components for the estimation of w′ should be noted.

(1) The mean squares corresponding to these three components of the block sum of squares have different expectations which are independent of the number of times the cubic lattice is replicated.

(2) If the whole cubic lattice is replicated twice, to estimate w' use component (a) and the additional $3(p^2-1)$ degrees of freedom for differences between blocks containing the same varieties. The resultant mean square is based on $3(p-1)(p+2)$ degrees of freedom with expectation $pA+B$.

(3) When inter-block mean square is less or equal to the intra-block mean square analyze as a randomized block design.

The formula for the variance of differences between adjusted varietal means can be simplified considerably. When making the test of significance and also when solving for values to use for adjusting varietal yields, λ and μ were used. That is,

$$\lambda = \frac{w - w'}{w + 2w'} = 0.4020, \qquad \mu = \frac{w - w'}{2w + w'} = 0.2867$$

let

$$\lambda' = \frac{\lambda}{p^2} = 0.01608, \qquad \mu' = \frac{\mu}{p^2} = 0.01147$$

then

$$V_m = \frac{2Ei}{3r}\left[1 + \frac{p^2}{p^2 + p + 1}\{6\lambda' + 3(p-1)\mu'\}\right]$$

$$V_m = \frac{2(.3682)}{3}\left[1 + \frac{25}{31}\{6(.01608) + 3(4)(.01147)\}\right]$$

$$V_m = \frac{2(.3682)}{3}(1.1888) = .2918$$

which is easier to solve than the formula as given on page 37. Also, note that $2Ei/3r$ is the regular formula for the variance of the differences between varietal means. The 1.1888 is the factor introduced by confounding.

Then, the effective error mean square per unit is $(.3682)(1.1888) = .4377$. This value compared with the error mean square (residual) secured from the ordinary randomized block analysis gives the efficiency of the cubic lattice design.

$$100 \times \frac{.5120}{.4377} = 117\%$$

Again, this is a much shorter process than that given on pages 38 and 39. In fact, table 9 gives the efficiencies accurately enough for most purposes. In this example

$$\frac{w}{w'} = \frac{2.7159}{.9002} = 3.017.$$

Reading from the table gives 116.8%.

From the standpoint of the applied statistician, the presentation in this bulletin is excellent. At each step, the mathematical discussion and formulae are followed by the corresponding numerical results from the example.

Sequential Analysis of Statistical Data: Applications. Prepared by the *Statistical Research Group, Columbia University* for the Applied Mathematics Panel, National Defense Research Committee, Office of Scientific Research and Development. SRG Report 255, Revised; AMP Report 30.2R, Revised. New York: Columbia University Press, September 1945. Pp. vii, 17; iv, 80; v, 57; iii, 25; iii, 18; iii, 39; ii, 41. $6.25. *Two reviews follow:*

REVIEW BY HENRY SCHEFFÉ
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THIS work constitutes a manual on the application of the Wald sequential probability ratio test to certain specific problems. In this test the observations are taken one at a time, and after each observation one of the following three actions is adopted: (1) the lot or process being inspected, or the statistical hypothesis being tested, is accepted, (2) it is rejected, (3) judgement is withheld and it is decided to take another observation. In cases (1) and (2) no further observations are taken. The present exposition is mostly in the language of inspection, although connections with experimentation are also noted. The descriptions of the properties of sequential tests are clear, and the instructions for their use are detailed; little background in the way of statistics or mathematics is demanded of the reader. The clarity is improved by the omission of some of the qualifications that a mathematician might be impelled to add; for example, the advantages of sequential testing are well summarized for non-mathematical readers in the following statement: "Thus, conspicuously good lots are quickly accepted, conspicuously bad lots are quickly rejected, and extensive inspection is needed chiefly by lots of doubtful quality—which is as it should be."

In every case treated here the probability of acceptance, when a given sampling plan is used, depends on a single unknown parameter θ. The graph of this probability is called the *OC* (operating characteristic) curve. The average number of observations required to reach action (1) or (2) above also depends on θ; its graph is called the *ASN* (average sample number) curve. The customer for the test chooses two distinguished values of θ, say θ_1 and θ_2, and ordinates of the *OC* curve at these values; ordinarily one of these ordinates will be chosen near unity and the other near zero. Considera-

tions governing the choice of θ_1, θ_2, and the corresponding ordinates are discussed in the introductory section 1. The *OC* curve which passes through the two chosen points is everywhere rising or everywhere falling, except in section 5 (the case of "two-sided alternatives"), where it is symmetrical in the line $\theta = \theta_1$ and falling for all θ greater than θ_1. The problems treated in sections 2 to 6 are the following:

2. θ is the unknown parameter (population proportion) of a binomial population.

3. There are two binomial populations with unknown parameters p_1 and p_2. In the first treatment θ is the "odds ratio," that is, the quotient of $p_1/(1-p_1)$ by $p_2/(1-p_2)$. In the second treatment θ is the "angular difference,"* that is, $\theta = \arcsin \sqrt{p_1} - \arcsin \sqrt{p_2}$.

4. θ is the mean of a normal population of known variance.

5. Ditto.

6. θ is the standard deviation of a normal population. In the first treatment the mean of the population is assumed known, in the second treatment, unknown (but the same for all θ).

Each of these sections describes both a graphic and a tabular procedure for analyzing the data, and each contains at least one numerical illustration. Except for section 5, each section contains a discussion of the *OC* and *ASN* curve; in this and other ways there is a considerable enlargement of the original "restricted" edition. Practically all the errors noted in that edition have now been eliminated. An extra section consisting of appendices treats among other matters the device of truncating the previously described sequential tests. This device, which is of great practical importance, consists of choosing beforehand an upper bound for the sample size, and whenever this size is reached without actions (1) or (2) having been taken in the usual way, one or the other is then taken, depending on the observations accumulated.

The organization and format are unusual. While the reviewer likes to see experiments in organizing and binding statistical material, he regrets finding this one somewhat unfortunate. The seven sections are separately bound in pamphlet form, stapled, not stitched, and they come in a ring binder, the whole arrangement being rather flimsy. When the pamphlets are used in the binder the book is hard to close unless a suitable process of shaking down is first used. The text is reproduced from typewritten copy by a photographic process. An effort has been made to make each of sections 2 to 6 practically self-contained, resulting in a large amount of repetition.

REVIEW BY B. L. WELCH
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THIS book is a revision and extension of work which was issued earlier as an O.S.R.D. report with restricted circulation. Its publication and

* The theoretical justifications of some innovations in connection with the angular transformation are not given. They will appear in *Techniques of Statistical Analysis for Selected Problems in Science, Engineering, Production, and Management* by the Statistical Research Group, Columbia University, to be published by McGraw-Hill Book Company in 1946.

general circulation to a wider public at this moment is welcome. In conjunction with the more theoretical papers on the same subject, which have now appeared in various statistical journals, it makes available a very clear account of a type of statistical procedure which has been strongly advocated in several quarters. It should be noted, however, that although sub-titled "Applications," the present book is only rightly so-called in the sense that it makes clear how to operate certain sampling procedures and how to analyse the observations resulting therefrom, assuming all along that these procedures are the ones most appropriate to the questions at issue. Except, perhaps, by implication, it scarcely touches the problem of indicating in practice the types of job for which the methods suggested are genuinely preferable to others which might be used.

The term "Sequential Analysis" has on occasion been applied to cover the analysis of data arising in all situations where sample sizes are not fixed in advance, but where the decision to stop sampling depends on the outcome of observations as they are made. It is not with such a wide meaning, however, that the term is used in the present book. The procedures described are the particular ones developed by Wald and his co-workers at Columbia University and any remarks in this review must therefore also be taken to refer only to these.

To illustrate the type of approach adopted we may instance one of the sections of the book, which deals with the case where, in the material sampled, the character in question is normally distributed with known standard deviation but unknown mean, and where a sampling plan and a rule for accepting or rejecting batches is required with the following properties: The chance of *accepting* material for which the true mean is m_1 should not exceed some specified small risk α; on the other hand the chance of *rejecting* material for which the true mean is m_2 should not exceed some specified small risk β. The suggested sampling procedure is then this: As every extra individual is added to the sample the decision is made whether to accept the batch sampled, reject it or take another observation. The decision is made on the basis of the running total, Σx, of the observations accruing to date, and sampling is continued till a decision one way or the other is obtained.

The claim that is made for this procedure as against a procedure that uses a sample number fixed in advance, is that it can satisfy the conditions laid down (i.e., give practically the same operating characteristic) with an appreciably smaller *average* sample size. More precisely it can be shown that, if the true mean m is in the vicinity either of m_1 or m_2, then the average amount of sampling will be appreciably less than if a fixed sample scheme were being used. However, if m is about half-way between m_1 and m_2, no such reduction in sample size will be obtained.

Results of this nature are interesting, but inconclusive if no attempt is made to relate them to the values of m likely to occur in a given practical case, and it is at this point that the present book proves somewhat disappointing. A basic criticism which has been made of Wald's work is that fre-

quently m will lie about half-way between m_1 and m_2 and that therefore appreciable average reductions in sampling size will not happen. Further, that even when m is either in the vicinity of m_1 or m_2 (so that the material sampled is in some sense abnormal) we may not be concerned so much with accepting or rejecting it, as with estimating its properties. For such purposes the smaller sample sizes then arising from the sequential method may be a positive disadvantage.

Whatever substance there may be in such criticisms must depend of course on circumstances and further discussion in abstract terms is probably not very profitable. In a book dealing with the "applications" of a statistical method, we might, however, have expected that more space would have been devoted to anticipating possible objections of this nature even if, in the opinion of the authors, such objections are not of great importance.

Other sections of the book deal in a very similar manner, with problems of controlling other features of the batch, e.g., proportions defective, variabilities, etc. Each section is bound separately in pamphlet form, and the whole series assembled in a ring type folder. This format is adopted so that the relevant section for any particular job can be abstracted and so be more conveniently available to anyone using it often. For library purposes a further edition of the book bound up in the usual manner would possibly be more convenient.

PUBLICATIONS RECEIVED

Statistical methodology publications received are listed elsewhere in this issue under the section "Statistical Methodology Index."

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Capital Goods Industries and Postwar Taxation. Chicago, Ill.: Machinery and Allied Products Institute (221 N. LaSalle St.), 1945. Pp. 22. Paper.

Commercial Policy in the Post-War World: Report of the Economic and Financial Committees. Series of League of Nations Publications, II, Economic and Financial, 1945.II.A.7. New York: Columbia University Press, 1945. Pp. 124. $1.25. Paper.

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Social Facts About Pittsburgh and Allegheny County: Vol. II, Pittsburgh Study Areas. Pittsburgh 22, Pa.: Bureau of Social Research, Federation of Social Agencies of Pittsburgh and Allegheny County, 1945. Pp. 64.

Union Labor in California, 1944. Report No. 1. San Francisco, Calif.: Division of Labor Statistics and Research, Department of Industrial Relations, State of California, October 1945. Pp. 46. Paper.

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Group Health Insurance and Sickness Benefit Plans in Collective Bargaining. *Helen Baker* and *Dorothy Dahl.* Research Report Series, No. 72. Princeton, N. J.: Industrial Relations Section, Princeton University, 1945. Pp. 94. $1.50. Paper.

The Development of Mathematics, Second Edition. *E. T. Bell.* New York: McGraw-Hill Book Co., Inc., 1945. Pp. xiii, 637. $5.00.

The British Balance-of-Payments Problem. *Arthur I. Bloomfield.* Essays in International Finance, No. 6 Princeton, N. J.: International Finance Section, Princeton University, 1945. Pp. 28. Paper.

Bioenergetics and Growth: With Special Reference to the Efficiency Complex in Domestic Animals. *Samuel Brody.* A Publication of the Herman Frasch Foundation. New York: Reinhold Publishing Corp., 1945. Pp. xii, 1023. $8.50.

Agricultural Adjustment and Income. *Arthur C. Bunce, William H. Fisher,* and *Earle L. Rauber.* Postwar Economic Studies, No. 2. Washington: Division of Administrative Services, Board of Governors of the Federal Reserve System, October 1945. Pp. iv, 66. $0.25. Paper.

Expenses and Profits of Limited Price Variety Stores in 1944: Chains and Independents. *Elizabeth A. Burnham.* Bureau of Business Research, Bulletin No. 123. Boston, Mass.: Division of Research, Harvard Business School, 1945. Pp. vi, 35. $1.50. Paper.

Effect of Federal Taxes on Growing Enterprises. *J. Keith Butters* and *John*

Lintner. Boston 63, Mass.: Division of Research, Harvard Business School, 1945. Pp. ix, 226. $3.00.

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Labor Savings in American Industry, 1899–1939. *Solomon Fabricant*. Occasional Paper 23. New York 23: National Bureau of Economic Research (1819 Broadway), November 1945. Pp. iv, 51. $0.50. Paper.

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Planning for Jobs: Proposals Submitted in the Pabst Postwar Employment Awards. Edited by *Lyle Fitch* and *Horace Taylor*. Philadelphia, Pa.: Blakiston Co., 1946. Pp. xxii, 463. $3.75.

Poona: A Socio-Economic Survey, Part I, Economic. *D. R. Gagdil*. Publication No. 12. Poona 4, India: Gokhale Institute of Politics and Economics, 1945. Pp. x, 300. Rs 15 or 30*s*.

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From Bretton Woods to Full Employment. *Dag Hammarskjöld*. Supplement A to Svenska Handelsbanken's Index, December 1945. Pp. 24. Paper.

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International Trade and Domestic Employment. *Calvin B. Hoover*. Committee for Economic Development Research Study. New York: McGraw-Hill Book Co., Inc., 1945. Pp. xii, 177. $1.75.

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Muller Ltd. (29 Great James St.), 1945. Pp. 268 9s. 6d.

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Prospects and Problems in Aviation: A Series of Papers Presented at the Chicago Forum on Aviation. Organized and directed by *Leverett S. Lyon* and *Lewis C. Sorrell.* Chicago 2, Ill.: Chicago Association of Commerce (1 N. LaSalle St.), 1945. Pp. v, 212. $2.00. Paper.

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STATISTICAL METHODOLOGY INDEX, NO. 3

A QUARTERLY GUIDE TO CURRENT LITERATURE

Edited by
OSCAR KRISEN BUROS
Rutgers University

This bibliographic service presents statistical methodology literature (articles, books, theses, and chapters) published in 1945 to date. Anonymous references are listed first; other references follow in alphabetical sequence by first-named authors. Volume number, issue number (in parentheses), pagination, and date of issue are given for each journal reference. Stars indicate books, theses, and pamphlets; asterisks indicate publications seen by the editor of this INDEX. *Authors of papers on statistical methodology are invited to send reprints to Oscar K. Buros, Rutgers University, New Brunswick, New Jersey in order to facilitate prompt and accurate listings. Foreign-language papers should be accompanied by English translations of titles. Information is desired about references omitted.*

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Statistical Theory: Some Recent Developments. Paul Blommers (Registrar and University Examiner, State University of Iowa). *R Ed Res* 15(5):423–40 D '45.* [303

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Ann Eug—Annals of Eugenics. Irregularly issued in recent years; 50s.(15s.); Galton Laboratory, University College, Gower St., London, W.C. 1, England.

ASTM B—ASTM Bulletin. 6 issues; $1.50(50¢); American Society for Testing Materials, 260 S. Broad St., Philadelphia 2, Pa.

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B Am Math Soc—Bulletin of the American Mathematical Society. 12 issues; $9; 450 Ahnaip St., Menasha, Wis.

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Edison Elect Inst B—Edison Electric Institute Bulletin. 12 issues; $2; 420 Lexington Ave., New York, N. Y.

Electrician—The Electrician. 52 issues in 2 vols.; 25s.(6d.); Bouverie House, 154 Fleet St., London, E.C.4, England.

Eng Insp—Engineering Inspection. Irregularly issued in recent years; 10s.(2s. 6d.); Institution of Engineering Inspection, 2 Caxton St., Westminster, London, S.W.1, England.

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Mat & Meth—Materials and Methods. Formerly *Metals and Alloys.* 12 issues; $2 (25¢); Reinhold Publishing Corp., 330 West 42nd St., New York 18, N. Y.

Math Student—The Mathematics Student. Published irregularly in recent years; G. A. Srinivasan, Presidency College, Madras, India.

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